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# CATALOGUE OF THE MACHAERIDIA

APR 1926
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BRITISH MUSEUM
(NATURAL HISTORY)

# CATALOGUE OF
# THE MACHAERIDIA
## (TURRILEPAS AND ITS ALLIES)
## IN THE DEPARTMENT OF GEOLOGY

BY
THOMAS HENRY WITHERS, F.G.S.
ASSISTANT IN THE DEPARTMENT

WITH EIGHT PLATES

BRITISH MUSEUM
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NATURAL HISTORY

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# PREFACE

When the Trustees gave authority for the preparation of a Catalogue of the Fossil Cirripedia, they agreed that there should be a preliminary volume describing certain Palaeozoic fossils hitherto assigned to the Cirripedia, but shown by the careful studies of Mr. Withers to depart from that Order in essential respects. This is the volume in question, and it deals with the four genera of which material has been accessible for study: *Lepidocoleus*, *Deltacoleus*, *Turrilepas*, and *Plumulites*.

An attempt has been made to refer to every described species of those genera, but in several cases the information or the material has not been enough to permit of final decision as to the validity of the species, and in many more cases it is not pretended that the diagnoses have reached their definitive form. It was, none the less, thought that a useful service would be performed by publishing the work with its novel views without further delay.

The work is a good deal more than a Catalogue of the specimens in the National Collection; but so far as that goes it is complete. The specimens preserved in the Geological Department are referred to by their register-numbers, and those are generally preceeded by an I. or an In. This needs some explanation. The separate register of fossil Arthropoda happened to begin with the Insecta, and for that reason the number was preceded by an I. Experience showed that this was confused by outside users with the cipher 1 or was frequently omitted. It has therefore been replaced in later books by the sign In.; when the number has become inconveniently large it is proposed to begin again with Is.; that can be followed by Ic., and so on.

References to literature are made according to the method advocated by a committee of the British Association and now in general use; that is to say, an author's name followed by a date enables the reader to find the work in the List at the end of the volume.

So much for the customary formal announcement. But this volume seems to demand from me a preface that shall be something more. For, in no merely official sense, I am responsible, first, for the inception of the work, and secondly, for a delay of many years in its publication.

Shortly after entering the Museum and beginning the study of the fossil Echinoderms, I became deeply interested in those strange stalked forms of Silurian age which the then Keeper of Geology had described not long before under the name Anomalocystidae (Woodward, 1880). The specimens of *Placocystites forbesianus* de Koninck that he had figured in both 1871 and 1880 came particularly under my notice, and I soon convinced myself of errors in his interpretation. Among those specimens was the fragment which he had determined as part of the stem of the Cystid. Several years later this specimen was referred by Dr. Cowper Reed (1901) to the species which he was the first to describe as *Turrilepas*?? *ketleyanus* Salter, but which he still inclined to regard as " the column of one of the Anomalocystidae."

The peculiar nature of the ornament in the Anomalocystidae had been noticed by E. Billings and H. Woodward in 1871 and by F. B. Meek in 1873, and its resemblance to that of the Cirripedia more or less emphasised. To the latter group I had been particularly attracted while a student at Oxford, but had no opportunity of studying its fossil representatives in the Geological Department, so that my doubts remained.

The determination of the Anomalocystidae as undoubted stalked Echinoderms, and of the fragment above alluded to as possibly part of a supposed Cirripede, *Turrilepas*, did not clear up all the mystery. What, after all, was *Turrilepas*? And why had the Anomalocystidae an ornament so like that of Cirripedes and so unlike that of any other echinoderm? Needless to say, I was not dallying with the idea that there was any genetic relation between Arthropoda and Echinoderma.

On the retirement of Dr. Henry Woodward in 1901, the fossil Arthropods came into my curatorial charge; but since that charge already comprised the Echinoderms, Brachiopods, Annelids, and temporarily various other groups, time did not permit any intensive study. Fortunately an advance in official position enabled me to claim the services of Mr. Withers. After some experience, I suggested that he should revise the collection of fossil Cirripedia, which had received no attention since Darwin's Monograph (1851–55), and it was agreed that he should begin

with the later forms, gradually working backwards until he could tackle the strange Palaeozoic fossils generally referred to the Order. Meanwhile, as opportunity offered, I continued the study of the Cystidea.

The plan worked admirably. Many interesting results were reached by Mr. Withers on the way, but it was again disturbing to find that certain Silurian fossils, which C. W. S. Aurivillius, the distinguished authority on Cirripedia, had claimed as *Scalpellum* were nothing else than the turret-like stems of *Pyrgocystis*, an Edrioasteroid (Bather, 1915).

It soon became clear that *Turrilepas* and its allies did not belong to the Cirripedia as usually understood; it was even doubtful whether they could be Arthropods, and the climax was reached when Mr. Withers showed me in a *Lepidocoleus* a fractured surface with distinct calcite cleavage such as any palaeontologist would have regarded as diagnostic of a fossil echinoderm.

This was about the beginning of 1916, and Mr. Withers might then have published the main results, as he naturally was eager to do. But to state a merely negative conclusion seemed unsatisfying, and, on this evidence alone, to assert the echinoderm nature of these fossils would have been not merely revolutionary but audacious. I urged Mr. Withers to obtain further evidence, both directly from the structure of the stereom, and indirectly by comparison with all the Palaeozoic fossils that had been ascribed to the Cirripedia, while I undertook to reconsider the relations to Echinoderma in the light of the new facts. But war duties intervened for both of us, and the accumulation of official work prevented me from concentrating attention on this problem.

Consequently, though I am responsible to a large extent for the form that the work has assumed, for every observation made and for the conclusions drawn in the main text all the credit is due to Mr. Withers.

As explained in the Introduction, it was thought advisable to adopt for this assemblage of fossils a new name with no connotation of affinity to any other group of organisms; and the name Machaeridia, based on the general form of the shell, was therefore chosen.

Whereabouts in the Animal Kingdom the Machaeridia should be placed is a question still unanswered, but Mr. Withers, who has made himself the recognised authority on fossil Cirripedes, firmly declines to place them in that Order.

Are the Machaeridia, then, Echinoderma after all? This is a question which, it seems to me, cannot be answered by an unconditional "Yes" or "No." If the answer be "No," then the Machaeridia constitute an entirely new Phylum. If the answer be "Yes," then the concept "Echinoderma" will need reconsideration. An attempt to elucidate these statements will not be out of place.

First, consider the crystalline cleavage of the stereom. This is characteristic of Echinoderma, and when observed in fragmentary fossils is supposed to be diagnostic. The cleavage has now been observed in five species of *Lepidocoleus*, but not in the plates of *Turrilepas* or of *Plumulites*. Few species of *Plumulites*, however, are so preserved that they would inevitably be expected to show it, but the stereom of *Turrilepas* and *Plumulites* had, like that of *Lepidocoleus ketleyanus*, a fine reticular structure which also resembles that characteristic of Echinoderma. It will, of course, be remembered that not all echinoderm fossils show the cleavage, and that the reticular structure is frequently obscured by the processes of fossilisation; it could not be detected by C. Stewart (*Geol. Mag.*, June, 1880) in *Placocystites forbesianus* itself. The peculiar granular structure of the stereom in *Plumulites peachi* may possibly be due to crushing or other subsequent changes; it can hardly be ascribed to a coarsely spicular constitution of the plates. Apart from this, it seems impossible to doubt the genetic affinity of *Lepidocoleus*, *Deltacoleus*, *Turrilepas*, and *Plumulites*, so that the statement in the diagnosis of the Machaeridia, that "the plates are composed of crystalline calcite," is justified. And if this be so, it certainly affords good grounds for placing the Machaeridia with the Echinoderma.

Suppose for the sake of argument that we accept this position, we have next to inquire with which known echinoderms the Machaeridia are most closely connected. The points to be considered are the bilateral symmetry; the imbrication of the plates; the peculiar growth-lines of the stereom, so different from the rhomb-ridge ornament of normal echinoderm plates; the muscle-scar on the inner side of each plate; and the arrangement of the plates to form an elongate, flexible, shell.

We may, I think, safely dismiss the idea that these fossils are the isolated arms of Asterozoa. It is equally impossible to compare them with Echinoidea. Among Holothurioidea, as at least one must agree with Mr. Withers, nothing like them is

known, whatever may once have existed. In any case the Holothurioidea are essentially pentamerous in main plan. The Pelmatozoa are even more pentamerous in structure; but there is one group usually assigned to them which shows no trace of pentamerism, but has a bilateral symmetry more or less marked. That is the Heterostelea, a compact group clearly limited within the ill-defined assemblage of Cystidea called Carpoidea by Jaekel, or the no better defined Amphoridea Haeckel em. Bather. The Heterostelea include the Anomalocystidae. The bilateralism of the Heterostelea is to a large extent secondary; but the framework on which it is imposed is not, so far as one can see, pentamerous.

The next feature, the imbrication of the plates, is seen in Edrioasteroidea, *e.g.* the *Pyrgocystis* already mentioned, and in various Heterostelea. It is this very imbrication which, by removing the plate from the stresses natural to a tessellated structure, and by providing a free apex, replaces the rhomb-ridge structure by parallel growth-lines. It is to an original imbrication that I would ascribe the peculiar ornament of most Anomalocystidae. There is a tendency for it to disappear as the plates become fixed, and a pustulate or even slight rhomb-ridge ornament may take its place.

The muscle-scar on the inside of each plate is certainly not a familiar feature in Echinoderma. One would not expect to see it in the plates of a relatively rigid theca. I have, however, recently discovered a similar structure on the inner face of some imbricating thecal plates, and the theca was that of an Anomalocystid, namely *Ateleocystites huxleyi* Billings, the specimen being one of the syntypes, 1392 b in the Victoria Museum at Ottawa. Muscles thus attached would provide a mechanism for the movement that I had previously inferred in other Heterostelea.

It is, of course, clear that all the features thus far mentioned are adaptations, any one of which might be found in almost any class of echinoderms. None of them, however, can be called other than unusual, and it is certainly remarkable that all of them should be found conjoined in the Machaeridia and in the Heterostelea. The least inference we seem entitled to make is that this conjunction of peculiar features, so far from weakening the evidence in favour of the echinoderm nature of the Machaeridia, is a strong confirmation of that hypothesis.

There remains the general form. This, undoubtedly, is very different from that of any echinoderm yet known to us. If

Mr. Withers is correct in regarding these shells as having enclosed the whole animal, and not as corresponding to a single organ, then the difficulty of comparison is increased. One was tempted to compare them with the stem of Heterostelea, as others had done, or with the so-called arm of the Heterostelean *Dendrocystis*; but if it were possible to regard them as such organs isolated from the body, we should be puzzled to find the creature to which they belonged. Mr. Withers seems justified in his conclusion. How then can we connect up the Machaeridia with the other Echinoderma?

Were speculation permissible in an official preface to an official publication, I should be tempted to turn yet again to the Heterostelea, and to give some grounds for thinking that they may have been descended from an elongate creature with food-intake at one end and vent at the other, and that they departed at a very early period from the main echinoderm stem, even before pentamerous symmetry had been impressed upon it. But those who wish to see such evidence as there is for this speculation must be referred to my paper on *Cothurnocystis* (1925, *Palaeont. Zeitschr.* VII. pp. 1–15).

After all, this conclusion, though reached by a totally different route, is essentially the same as the conclusion previously expressed concerning the ancestor of all Echinoderms, namely that it was the imagined *Dipleurula* (Bather, 1900, Lankester's Zoology). The differences between the Heterostelea and all other Echinoderma, on the present hypothesis, follow on the mode of attachment. The *Dipleurula* that became fixed near its mouth gave rise to the Primitive Pelmatozoon and so to all the pentamerous Echinoderma with contorted or coiled gut. The *Dipleurula* in which the point of attachment either was from the beginning nearer the middle of the body or migrated to that position, gave rise to the Heterostelea, in which there was no torsion of the gut and never a position so upright as to induce pentamerism.

Now suppose that the *Dipleurula*, instead of becoming permanently attached, were to follow the direction of cephalisation and locomotion; it would become vermiform and would probably increase its slight initial metamerism. Assume that the tendency to deposit a calcite stereom was already possessed by the *Dipleurula*, then this worm-shaped creature would become clothed with plates which would have to be flexibly jointed or imbricate. If, as would be natural if not inevitable, the ventral surface remained

unplated during locomotion, then the creature would in the fossil state resemble one or other of the Machaeridia.

Whether the cancellated plate indicates fixation or not we cannot be certain. Possibly it is the sign of a fixation in the earliest stages of growth only, but just enough to determine the direction of imbrication and of plate-growth. It is quite concordant with the preceding hypothesis.

On that hypothesis, the question is again insistent: Can the Machaeridia be called Echinoderms or not? The first answer is that, on that hypothesis, they have just as good claim to the title as have the Heterostelea. The second answer is that both Machaeridia and Heterostelea come within the limits of the strict diagnosis of Echinoderma, *i.e.* the first paragraph of that which I published in 1900 (Lankester's Zoology); they do not, so far as one can see, agree with either the second or third paragraphs of that diagnosis, which, with intention, were not made exclusive.

Expressed in another way, the tentative conclusion is that the Heterostelea and Machaeridia are among the earliest offshoots from the Echinoderm stem of which we have knowledge; that, though in several respects the Machaeridia resemble certain Heterostelea, yet they are not Heterostelea, and are not descended from Heterostelea; that these two Classes, for so on this hypothesis one must regard them, differ from all other Classes of Echinoderma in not having had pentamerism and the other echinoderm features impressed on them during an ancestral period of fixation.

F. A. Bather.

Department of Geology,
British Museum (Natural History),
*February* 17, 1926.

# AUTHOR'S PREFACE

My thanks are due to Prof. W. S. Boulton, Birmingham University, and Prof. J. W. Carr, University College, Nottingham, for information regarding figured specimens of *Turrilepas wrightiana*; to Dr. M. Remeš for sending me the holotype of *Lepidocoleus latus* for description; to Dr. R. Ruedemann for furnishing a photograph of his *Lepidocoleus reinhardi*, and for information regarding type-specimens in the New York State Museum; to Prof. J. E. Marr, F.R.S., Dr. F. R. Cowper Reed, and Mr. Henry Woods, F.R.S., for the loan of specimens, and for facilities given me at the Sedgwick Museum, Cambridge; to the Director of the Geological Survey and Dr. F. L. Kitchin for the loan of specimens where available; to Dr. W. T. Calman, F.R.S., and to Mr. W. N. Edwards for kindly reading part of the MS.; and to Mr. C. Davies Sherborn for bibliographic help.

Mr. W. Campbell Smith gave me much assistance in the examination of the sections and preparations of the shell, as did also Mr. E. D. Mountain, who in addition tested fragments of the shell for chitin.

Above all I am indebted to Dr. F. A. Bather, who not only gave me much encouragement in the initial stages of this investigation, but later made many helpful criticisms, of which I have taken full advantage. He also, when in Prague, took squeezes of the more important of Barrande's types in the Bohemian Museum, and when in Albany made drawings and notes of the specimens described by Hall and Clarke, all of which have been taken into careful account in formulating the conclusions of this work.

T. H. Withers.

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# INTRODUCTION

## *The so-called Palaeozoic Cirripedia*

Before any real progress can be made in our knowledge of the phylogeny of the Cirripedia, it becomes necessary to get a clear conception of the morphology of the Palaeozoic fossils referred to that group. Only in this way can we hope to settle the difficult question whether these forms are Cirripedes or not.

Some of these Palaeozoic fossils, such as *Protobalanus hamiltonensis* R. P. Whitfield (1888), and *Palaeocreusia devonica* J. M. Clarke (1888), from the Middle Devonian of New York, *Hercolepas signatus* (Aurivillius, 1892) from the Upper Silurian of Gotland, and *Eobalanus* (*E. informans* and *E. trentonensis* Ruedemann, 1924) from the Ordovician (Utica and Trenton) of New York, have been considered to be the ancestors of the sessile or unstalked Cirripedes. While these forms have a superficial resemblance to Cirripedes, the more we know about them the more do they appear morphologically inconsistent with the members of that group, and from the phylogenetic standpoint it is extremely improbable that they can have any connection with the later forms. In fact there is no real evidence that they are Cirripedes at all. They are of extreme rarity, for, except in the case of *Eobalanus*, which is represented by four specimens, only single specimens are known. These fossils have been already discussed by me in two papers (1915, 1924), but only specimens of *Eobalanus* have been examined. None is represented in the British Museum.

Other Palaeozoic fossils, such as *Strobilepas* (*S. spinigera* J. M. Clarke, 1888), known from a single specimen from the Middle Devonian of New York, *Eopollicipes siluricus* (R. Ruedemann, 1901, p. 578; 1912, p. 122; 1924, p. 539), known by detached plates from the Ordovician (Utica) of New York, and *Lepidocoleus*, *Plumulites*, and *Turrilepas*, forms very widely distributed in the Palaeozoic rocks, have been considered to be the ancestors of the stalked Cirripedes.

In the two papers just mentioned (Withers, 1915, 1924) the genera *Lepidocoleus*, *Plumulites*, and *Turrilepas* were not discussed in any great detail, and, beyond pointing out the distinction between them, very little was said concerning their structure. The opinion was expressed, however, that, while it was doubtful whether some of the fossils referred to those genera really belonged to them, it certainly still remained to be proved that any of the fossils were rightly placed in the Cirripedia.

Although as a rule only the disconnected plates are preserved, still there have been found individuals of *Lepidocoleus, Plumulites,* and *Turrilepas* which variously approach completeness. Despite the existence of such good material, extremely little is known concerning the mutual relationship of those forms, or concerning their structure, and in no case has the precise relation of the animal to the shell been shown. Indeed, the figures and descriptions of *Turrilepas* and *Plumulites* so far published give quite an erroneous idea of their structure. It is this want of definiteness in our knowledge of *Turrilepas* H. Woodward and *Plumulites* Barrande, which were considered to be synonymous even by their own authors, that has retarded any advance in our conception of their relations. Thus, some of the fossils referred to *Plumulites* have been included in the genus *Lepidocoleus* C. L. Faber, notably the genotype *L. jamesi* (Hall & Whitfield); Barrande described some plates of *Lepidocoleus* under his genus *Plumulites* (*P. squamatula*); and Dr. H. Woodward subsequently described a species of *Plumulites* under his genus *Turrilepas* (*T. canadensis*). Since the original authors themselves confused their own genera, it is not surprising that other authors, in describing many new species of these forms, should have made mistakes in their generic reference. Disconnected plates of these fossils continue to be described, and they are referred to *Lepidocoleus,* to *Plumulites,* or to *Turrilepas,* apparently without the author having the least idea of the structure and shape of the plates which built up the shell of the forms included in those genera. The result is confusion. The structure of these three genera has therefore been investigated anew, and it is hoped that the fresh description now given will render it possible to refer each species to its proper genus, to show the relation of the soft parts to the shell, and to reach some more satisfactory conclusion as regards the zoological position of the assemblage.

More than 300 specimens are dealt with in the following pages, and incidentally three new species of *Lepidocoleus* are described from the Ordovician and Silurian of North America, two from the Silurian of England, and one each from the Silurian of Burma and the Devonian of Moravia. A new species of *Plumulites* is described from the Ordovician of England, and another from the Ordovician of North America, and a new genus and species, *Deltacoleus crassus,* is founded on some plates from the Ordovician of Scotland.

## *Collections utilised*

The material examined comes from many sources, but that in the British Museum is by far the most extensive and important, comprising as it does as much as two-thirds of the total. The chief collectors whose specimens have thus enriched the national collection have been the following :—

ALLPORT, Samuel, who, after residence in Brazil, settled at Birmingham and collected from the Silurian rocks of the neighbourhood. His collection, purchased in 1871 and 1873, includes the specimen of *Turrilepas wrightiana* figured by H. Woodward, 1865, pl. xiv, fig. 1 g, with others of the same species and of *Lepidocoleus ketleyanus* now figured.

BARRANDE, Joachim, the great palaeontologist of Bohemia, from whom extensive series of specimens were purchased in 1855, 1856, and 1857. Among them are examples of *Lepidocoleus squamatula* and *Plumulites fraternus*.

GRAY, Elizabeth (Mrs. Robert Gray), of Edinburgh, who to the very close of a long life collected from the Palaeozoic rocks of Girvan, Ayrshire. Her extensive and important collection, purchased in 1920, includes the types and figured specimens of *Lepidocoleus grayae*, *Deltacoleus crassus*, *Plumulites peachi*, and *P. scoticus*, with many other examples of the two latter species.

GRAY, John (of Hagley, near Stourbridge), who owned quarries in the Wenlock Limestone at Dudley, amassed remarkable collections, of which large portions were purchased in 1861, 1869, and 1889. These include, among others, the holotype of *Chiton* [now *Turrilepas*] *wrightianus* and a figured specimen of *Lepidocoleus ketleyanus*.

HOLL, Harvey Buchanan, who lived at Malvern, collected in the neighbourhood, chiefly in the Wenlock Beds. His collection, purchased in 1887, includes the holotype of *Lepidocoleus britannicus* and a figured specimen of *Turrilepas wrightiana*.

JOHNSON, Henry, civil and mining engineer, of Dudley, collected many choice specimens from the Wenlock Beds. His collection, purchased in 1886, includes, among others, the specimen of *Turrilepas wrightiana* figured by H. Woodward, 1865, pl. xiv, fig. 1 h, and figured specimens of *Lepidocoleus ketleyanus*.

KETLEY, Charles, civil and mining engineer, of Smethwick, near Birmingham, collected from the Wenlock Beds of Dudley, the Malvern Tunnel, and district. Small purchases made from him in 1866, 1869, 1870, 1873, and 1874 include specimens of *Lepidocoleus ketleyanus* and figured specimens of *Turrilepas wrightiana*. His main collection is in Birmingham University.

SMITH, W. R., of Belleville, Ont., where he collected in the Trenton Limestone. A series from his collection, purchased in 1909, includes the holotype of *Lepidocoleus sigmoideus*.

ULRICH, Edward O., of the United States National Museum, formerly lived at Newport, Kentucky. In 1898 the Trustees purchased from him a collection of Polyzoa, and specimens of Machaeridia which include the holotypes of *Lepidocoleus strictus* and *L. ulrichi*, and specimens of *L. jamesi*.

The present work is nominally a Catalogue of this material preserved in the Geological Department, and, except when otherwise indicated, in the following pages the register numbers are those of the Department. But to make the survey as complete as possible there have been included notes or descriptions of all the forms known to me, especially those in the Sedgwick Museum, Cambridge. The chief stress has throughout been laid on those specimens, wherever they may be, which elucidate the morphology of the group.

### *The Machaeridia delimited*

No attention is here paid to any genera, such as *Strobilepas* J. M. Clarke (1888, p. 212) and *Eopollicipes* Ruedemann (1924, p. 539), of which the actual remains have not been available for independent examination. In dealing with such problematical forms it is quite unsafe to rely on the figures of other writers, especially when they are professedly reconstructions.

The four genera to which attention is restricted, namely, *Lepidocoleus*, *Plumulites*, *Turrilepas*, and *Deltacoleus*, clearly constitute a natural group, which, whether it be regarded as a Family, an Order, or a Class of some known Phylum, or as representing some branch of the Animal Kingdom hitherto unrecognised, is capable of objective description in terms common to all its members. Although this group corresponds in the main with the assemblage which various writers have regarded as a Suborder of Cirripedia Thoracica, giving it various names appropriate to that conception, it has been thought better in this work to cut adrift from the Cirripedia and to give a fresh name that should suggest no relationship. In allusion to the somewhat sabre- or blade-shaped form of the fossils, the name Machaeridia (*μαχαιρίδιον*, diminutive of *μάχαιρα*, *sabre*) has been selected.

Further discussion concerning the zoological position of the Machaeridia is reserved for a final chapter, after the description of the constituent genera and species.

# SYSTEMATIC DESCRIPTION

## Group MACHAERIDIA nov.

Palaeothoracica, Stromer v. Reichenbach, 1909, p. 278.
Turrilepadomorpha, Pilsbry, 1916, p. 13.
Protocirripedia, Joleaud, 1916, p. 7.

(See text-figs. 7–23, pages 74, 75)

Provisional Definition, with Terminology. Marine Animals (Metazoa), in which all is enclosed in an elongate, bilaterally symmetrical, blade-shaped shell, composed of an even number of longitudinal *columns* of plates. (As at present known the number of columns is two or four; the number of plates in a column is from thirteen to sixty; and the plates of one column tend to alternate with those of the adjacent column or columns.) The two columns (*i.e.* the *inner* columns when four are present) adjoining one margin of the blade are composed of plates that are *keeled* or bent round to form a broad *back*, along the median line of which they meet firmly, so that this may be called the *fixed margin*; the portions of two columns (*i.e.* the two *outer* columns when four are present) adjoining the other margin of the blade meet there in a sharp knife-edge, along which the shell could open, so that this may be called the *free margin*. The shell tapers somewhat towards its two ends, at one of which certain plates are more or less modified, presumably for attachment, so that this may be called the *proximal* end or *base*; the opposed or *distal* end is merely tapered off. The remaining constituent plates are oblong (in forms with two columns) or subtriangular (in forms with four columns), but in each case are attached by the proximal margin, which is overlapped by the distal portion of the adjacent proximally situate plate, producing distalward imbrication. In each (admedian) plate the corner at the distal end of its admedian margin is the *apex* or umbo about which well-marked growth-lines are concentric, being also parallel to the proximal margin. The outer portion of each keeled plate bears on its inner surface a *scar*, presumably due to the attachment of a muscle or ligament. The plates are composed of crystalline calcite, and on their inner surface can be detected a minute irregular reticular ornament.

The genera under discussion fall into two divisions according as the columns of plates are two or four in number.

The former division includes only *Lepidocoleus*, which has already given its name to a Family, the LEPIDOCOLEIDAE of J. M. Clarke (1896). The latter division, corresponding to the TURRILEPADIDAE of J. M. Clarke (1896), includes *Turrilepas* and *Plumulites*, genera considered to be so similar in structure that their independence has been denied by many authors, and *Deltacoleus*.

There is at present nothing to indicate which, if either, of these Families preceded the other in time, which, in other words, is morphologically the more ancestral. It is therefore convenient to deal first with that in which the structure is the more simple.

## Family *LEPIDOCOLEIDAE*

DIAGNOSIS. Machaeridia with an elongate shell composed of two columns of more or less imbricating, transversely oblong, slightly alternating plates, slightly overlapping on the fixed margin, and so curved transversely as to give the shell an elongate cordiform cross-section.

### Genus LEPIDOCOLEUS Faber

1875. *Plumulites* Barrande: Hall & Whitfield, Geol. Surv. Ohio, Palaeont., II, pt. ii, p. 106.
1886. *Lepidocoleus* Faber, *Journ. Cincinnati Soc. Nat. Hist.*, IX, p. 15.
1888. *Lepidocoleus* Faber: Hall & Clarke, Palaeont. New York, VII, p. lxiv.
1896. *Lepidocoleus* Faber: J. M. Clarke, *Amer. Geol.*, XVII, p. 139.
1914. *Lepidocoleus* Faber: Moberg, *Kgl. Fysiogr. Sällsk. Handl.*, N.F., XXVI, No. 1, p. 13.
1915. *Lepidocoleus* Faber: Withers, *Geol. Mag.* (dec. vi), II, p. 121.
1922. *Lepidocoleus* Faber: Withers, *Ann. Mag. Nat. Hist.*, (9), IX, p. 653.

DIAGNOSIS. This being the only known genus, the diagnosis is the same as that for the Family.

GENOTYPE. *Lepidocoleus jamesi* (Hall & Whitfield).

SPECIES AND DISTRIBUTION. The genus was founded by Faber (1886) for an apparently entire specimen from the "Hudson River group" (= Cincinnatian) of Cincinnati. This he referred to the Cirripedia and considered as specifically identical with *Plumulites jamesi*, previously based by Hall & Whitfield (1875) on disconnected plates from the same rocks. S. A. Miller (July, 1875), who figured a fairly good specimen from Lebanon, O., said that such plates occurred right through the Cincinnati group.

The record from the Lower Ludlow is based on a specimen with two plates in the Museum of Practical Geology, registered 28281, from Vinnal Hill, Ludlow.

Including the new species now to be described, the distribution of the species of *Lepidocoleus* may be tabulated as follows :—

| | | | |
|---|---|---|---|
| Middle Devonian. | | | *L. latus* n. sp. Moravia. |
| Lower Devonian. | *L. illinoiensis* Savage (1913). Upper Oriskany, Union Co., Ill.<br>*L. polypetalus* J. M. Clarke (1896). Lower Helderberg, N.Y. | | |
| Upper Silurian | | *L.* sp. Lower Ludlow, Ludlow. | |
| Middle Silurian. | *L. reinhardi* Ruedemann (1925). Bertie Waterlime, Buffalo, N.Y. | | |
| | *L. sarlei* J. M. Clarke (1896) Clinton group, Rochester, N.Y. | *L. ketleyanus* Reed (1891). Dudley.<br>*L. britannicus* n. sp. Malvern. Both Wenlock Beds. | ? *L.* sp., Aurivillius (1892). Bede, Gotland.<br>*L.* sp., Hede (1917). Between *Cyrtograptus* & *Colonus* Beds, Gotland. |
| Lower Silurian. | *L. strictus*, n. sp. Richmond group, Indiana. | *L. turnbulli* n. sp. Cartlett Beds, Haverfordwest. | *L.* sp. er, Bohemia.<br>*L. birmanicus* n. sp. Panghsapye Beds, Burma. |
| Upper Ordovician. | *L. jamesi* Hall & Whitf. (1875). "Hudson River group," Cincinnati.<br>*L. jamesi* ? Utica Shale, Kentucky. | *L. suecicus* Moberg (1914). *Phacops mucronatus* Beds, Lake District, Yorks., & Lancs. Shoalshook Limest., Haverfordwest. Dufton Shales, Cumberland. Applethwaite Beds, Lake District. *Dicranograptus* Shales, Haverfordwest.<br>*L. grayae* Withers (1922). Drummuck group, Girvan. | *L. squamatula* Barrande (1872). d5, Bohemia.<br>*L. suecicus* Moberg (1914). Black Trinucleus & Brachiopod Shales, Sweden. |
| Middle Ordovician. | *L. jamesi*? Trenton group, N.Y.<br>*L. ulrichi* n. sp. Trenton group, Minnesota.<br>*L. sigmoideus* n.sp. Trenton group, Ontario. | | |

Structure. The outer structure of the shell has been previously described by Faber (1886), Miller & Faber (1894), J. M. Clarke (1896), and Withers (1922).

There are but two columns of plates, and they are so arranged as to form an elongate, blade-shaped body, which permits of no additional columns. The apices lie next the broad back, and the two columns are consequently in close apposition. The number of plates in a column apparently varies with the species, *L. sarlei* having thirteen, and *L. sigmoideus* n. sp. over fifty-five and probably sixty. Each plate is distinctly asymmetrical, but corresponds almost exactly in shape and size with the adjoining plate in the opposing series. Only a narrow distal portion of each plate is exposed, for each plate overlaps the succeeding one by from one-half to two-thirds of its height, the degree of overlap varying with the species. The plates of the two columns alternate regularly with each other on the back, and in consequence each plate in one column is a little in advance of the nearest adjoining plate in the opposing column. This alternation is very slight or non-existent in *L. britannicus* and *L. ketleyanus*, but is strong in *L. sarlei* and *L. illinoiensis*.

The plates of both columns are more or less sharply folded inwards and downwards near and parallel to their fixed margin, so as to form a median groove along the back. The plates of the left-hand column have a slightly larger portion so folded, and the extreme edge of this portion is somewhat turned upwards beneath the down-turned edge of the right column, forming a hinge, which owing to the slightly greater width of the left-hand plates is in the middle line of the back. In consequence of the shell tapering towards each extremity, the plates vary somewhat in shape according to their position in the shell.

Along the free margin the plates are only in loose apposition, and it is presumably along this margin that the shell opened; in the holotype of *L. illinoiensis* one side of the shell has been compressed beyond the other. The plates near the distal end, at any rate in *L. sarlei*, appear to increase in height. The terminal plates are acuminate, and that of the right-hand column is smaller and overlapped on its fixed margin by the left-hand terminal. At the base, on the left side, there is a comparatively large semicircular plate; and it is probable that the complete shell had a similar but smaller plate on the right side.

Both in *L. sarlei* and *L. jamesi* there is a fairly strong bend of the proximal extremity towards the free margin. In a specimen of *L. ketleyanus* (Pl. III, fig. 4) the whole shell is curved towards the free margin, while the holotype of *L. reinhardi* (text-fig. 2) is curved away from the free margin. In the specimen figured by H. Woodward (1871) as the stem of a Cystid (Pl. III, fig. 7) the shell viewed from the free margin shows a slight sigmoid curve. *L. strictus* (Pl. II, fig. 14), viewed from the fixed margin, shows this to a marked degree, indeed the whole shell is thus

curved, and so it is in the holotype of *L. sigmoideus* (Pl. I, fig. 1) except that the curvature is from the fixed to the free margin. It may be inferred from these facts that the shell was ordinarily straight, but could be bent by the animal to some extent in any direction, and it is very probable that the plates were capable of movement upon one another, and that the shell could be extended.

Concerning the inner structure of the shell in *Lepidocoleus*, and its relations to the soft parts, scarcely anything has been known hitherto. Removal of the matrix from the inner surface of three plates of *L. jamesi* (In.17510, Pl. I, fig. 6; In.17511–12) revealed in each of them a well-marked scar, precisely similar to that observed in the median plates of *Turrilepas*. In specimens of *L. suecicus* (I.14425, Pl. II, fig. 1; In.23968) there are four plates in which a similar scar can be seen, and Moberg (1914, July, p. 14) states that a scar was observed in each of four plates of the same species seen by him. A similar scar has also been exposed in a plate of *L. squamatula* (In.17506). The plates of *L. ketleyanus* are small, very often cracked, and difficult to extract whole from the matrix. One plate (Pl. III, fig. 10), however, thus prepared, shows a scar rather near the umbonal margin, but the scar is somewhat more angular at the top than in the other species and has the appearance of an inverted **V**. Since a scar has been found in all the thirteen plates of *Lepidocoleus* fossils in which the inner surface has been cleaned, it appears justifiable to conclude that in this genus, as in the case of the inner columns of *Turrilepas*, all the plates of the two columns possessed such a scar. This is confirmed by the examination of imprints. The Upper Ordovician and Lower Silurian species from Cumberland and Haverfordwest (*L. suecicus*, *L. turnbulli*), and the Lower Silurian species from Burma (*L. birmanicus*), are for the most part represented only by imprints of the outer and inner surfaces of the scattered plates, the shell itself having been dissolved. No less than eighteen plates, distributed among these three species, show the imprint of the inner surface, and each of these retains the distinct impression of a scar.

In short, *Lepidocoleus* has an elongate, blade-shaped shell, composed of two columns of plates in close apposition, and the presence of a scar on each of the plates suggests, as in *Turrilepas*, that the animal was attached to these along the whole extent of the shell.

The species of *Lepidocoleus* will now be described: first those of which a united shell is available, and afterwards those based on isolated plates. Each of these sets is dealt with in ascending geological order.

*Species represented by a united Shell*

## *LEPIDOCOLEUS SIGMOIDEUS* n. sp.

(Plate I, fig. 1)

Diagnosis. Shell (incomplete) with fifty-five plates to a length of 64 mm. Width 6·5 mm., equal to the height of the exposed surface of seven plates. Ornament: fine, close-set, raised lines numbering about eight to nine to 1 mm.

Distribution. Middle Ordovician, Trenton Limestone: Belleville, Ontario, Canada.

Holotype. The unique specimen I.14841 (W. R. Smith, No. 132).

From many points of view this is one of the most important of the known specimens of *Lepidocoleus*, and it is all the more unfortunate that there should be even the slightest doubt as to its provenance. While the other specimens obtained from Mr. W. R. Smith were labelled "Belleville," with this particular specimen there was nothing more than "*Stenaster* ?, 132." Consequently it is presumed, although most probably with justice, that this specimen came from the same horizon and locality as the others, with which it agrees in colour and matrix.

Description. Owing to compression the shell, which is embedded in a thin black shale, has been completely flattened with the right side uppermost, but the broad edges of the plates of the left column are also seen, separated by a deep depression from those of the right. Towards the distal end a linear furrow, due to compression, emerges from the median depression and extends irregularly down the shell for about two-thirds of its extent. Shell strongly curved sigmoidally in the plane of compression.

The specimen was in four pieces, but the fractured ends of the three distal pieces have now been fitted close together. Although the fourth piece does not fit exactly, the peculiar way in which the specimen has been compressed hardly leaves room for doubt that this piece belonged to the same individual.

Altogether there are fifty-five plates, forty-one in the three distal pieces, and fourteen in the proximal piece. There may be one or more plates missing between the third and fourth pieces, but as the distal end of the shell is complete, and the proximal end already shows on its fixed margin distinct evidence of rapid tapering, there could not have been many more than five plates, making sixty or more plates to a column. Length of shell, as preserved, 64 mm., width 6·5 mm., or equal to the height of the exposed surface of seven plates. The growth-lines are close-set, fine, and raised, and, except below the apex, the vertical lines only are visible, owing to the narrowness of the exposed surface; the vertical lines number eight to nine to a millimetre, but where they run parallel to the proximal margin

they are closer together and number about eighteen to a millimetre.

Comparison with other species. The length of the shell (64 mm.) and the large number of plates, certainly fifty-five, and when complete at least sixty, appear to separate this species from the remaining North American Ordovician species; *L. jamesi* has only fifteen plates to a complete shell having a length of 12 mm., and *L. ulrichi* n. sp. has eleven plates to an incomplete shell measuring 9·9 mm., and when complete probably had no more than about twenty plates. Moreover, the width of the shell (6·5 mm.) is equal to the height of the exposed surface of seven plates. In these characters it differs also from the European Ordovician species, and it has the ornament finer and more close-set than in most species. *L. jamesi* especially has more wide-spaced growth-lines. A comparison with the Middle Silurian *L. reinhardi* is given on p. 19.

## *LEPIDOCOLEUS ULRICHI* n. sp.

(Plate I, figs. 2, 3, text-fig. 1)

Diagnosis. Shell with probably about twenty-two plates in a column and estimated to attain a length of about 20 mm. Width 4·6 mm., equal to the height of the exposed surface of five plates. Ornament: close-set, raised, fine lines, numbering about eight to nine to 1 mm.

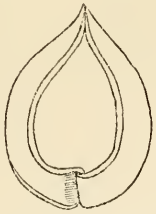


Fig. 1.—*Lepidocoleus ulrichi* n. sp. Proximal end of holotype. × 10 diam. Middle Ordovician, Trenton group, Prosser Limestone (*Clitambonites* bed): Cannon Falls, Minn., U.S.A.

Distribution. Middle Ordovician, Trenton group, Prosser Limestone (*Clitambonites* bed): Cannon Falls, Minnesota, U.S.A.

Holotype. The unique specimen I.7245, being the proximal part of a shell (Pl. I, figs. 2, 3), (E. O. Ulrich Coll.).

Description. The specimen is entirely free from matrix, and comprises probably about the proximal half of a shell. In all probability the terminal paired plates are the only ones absent from the proximal extremity. From the fixed margin can be seen the remains of eleven plates, for the upper part of the specimen is broken obliquely downwards towards the free margin. In length the fragment measures 9·9 mm., and its greatest

breadth is 4·6 mm. There is little or no alteration of the plates. Only the proximal plate (probably the true second proximal) is wholly exposed, and this has a height of 1·3 mm., and a width of 3 mm. The exposed surface of the other plates measures 0·9 mm. (= about ·7 of the height of the plate). The distal margin of each plate is gently convex, and the proximal margin (seen only in the proximal plate) concave. Fixed margin convex; free margin convex, and forming with the proximal margin a broadly rounded angle.

The growth-lines are close-set, fine, and raised, and, except below the apex, the vertical lines only are visible, owing to the narrowness of the exposed surface; these vertical lines number eight to nine to a millimetre, but where the growth-lines run parallel to the proximal margin they are closer together and number about eighteen to a millimetre.

Comparison with other species. This species is superficially like the much later *L. sarlei* from the Clinton group (Middle Silurian). *L. sarlei*, however, has only thirteen plates to a complete shell having a length of 23 mm., but in the present species there are as many as eleven plates to an incomplete shell having a length of only 9·9 mm., and with certainly one more plate at the base, and several more at its upper extremity. In *L. sarlei* the width is equal to the height of the exposed surface of three plates, while in *L. ulrichi* the width is equal to the exposed surface of five plates.

*L. ulrichi*, although so different in appearance, seems to be more nearly related to *L. sigmoideus*, and in fact the distribution of the growth-lines is seemingly identical. It does not appear probable, however, that *L. ulrichi* could have had so many plates or so great a length as *L. sigmoideus*, and since in *L. sigmoideus* the width (6·5 mm.) is equal to the height of the exposed surface of seven plates, and in *L. ulrichi* the width (4·6 mm.) is equal to the height of the exposed surface of five plates, it would seem advisable to keep the latter as a separate species. *L. jamesi* differs from both in the more wide-spaced growth-lines.

## *LEPIDOCOLEUS JAMESI* (Hall & Whitfield)

(Plate I, figs. 4–6)

1875. *Plumulites jamesi* Hall & Whitfield, Geol. Surv. Ohio, Palaeont., II, pt. ii, p. 106, pl. iv, figs. 1–2 (non fig. 3 = *Turrilepas wrightiana* de Koninck).

1875. *Plumulites* (?) *jamesi* Hall & Whitfield: Miller, *Cincinnati Quart. Journ. Sci.*, II, p. 275, fig. 19.

1880. *Plumulites jamesi* Hall & Whitfield: Ulrich, Cat. Foss. Cincinnati Group, p. 8.

1886. *Lepidocoleus jamesi* (Hall & Whitfield): Faber, *Journ. Cincinnati Soc. Nat. Hist.*, IX, p. 15, pl. i, figs. A–F.

1888. *Lepidocoleus jamesi* (Hall & Whitfield): Hall & Clarke, Palaeont. New York, VII, p. lxiv, text-fig.

1889. *Plumulites jamesi* Hall & Whitfield: Lesley, Geol. Surv. Pennsylvania, Rep. P4, II, pp. viii, 723, figs. (right-hand fig. = *T. wrightiana*).
1889. *Lepidocoleus jamesi* (Hall & Whitfield): Miller, N. Amer. Geol. Pal., p. 553, figs. 1022–1023.
1894. *Lepidocoleus jamesi* Faber: Miller & Faber, *Journ. Cincinnati Soc. Nat. Hist.*, XVII, p. 32.
1896. *Lepidocoleus jamesi* (Hall & Whitfield): Clarke, *Amer. Geol.*, XVII, p. 143, pl. vii, fig. 9.
1901. *Lepidocoleus jamesi* (Hall & Whitfield): Ruedemann, *Bull. N.Y. State Mus.*, No. 42, p. 521 (footnote), pl. ii, fig. 10 (? non fig. 12; fig. 11 = *Plumulites trentonensis* n. sp.).
1901. *Lepidocoleus jamesi* (Hall & Whitfield): Ruedemann, *Bull. N.Y. State Mus.*, No. 49, p. 87, pl. iv, figs. 16–19.
1908. *Lepidocoleus jamesi* (Hall & Whitfield): Cumings, 32nd *Ann. Rep. Geol. Indiana* (1907), p. 1050, pl. liii, figs. 13–13 d.
1919. *Lepidocoleus jamesi* (Hall & Whitfield): Bassler, Maryland Geol. Surv., Cambrian & Ordovician, p. 371, pl. lv, figs. 2–4, pl. lii, figs. 24, 25 (non pl. lv, fig. 1 = *T. wrightiana*).
1924. *Lepidocoleus jamesi* (Hall & Whitfield): Foerste, *Mem. Geol. Surv. Canada*, No. 138, p. 255, pl. xlv, figs. 9 a, b, c.

Diagnosis. Shell with probably fifteen plates in a column, and attaining a length of about 12 mm. Width equal to the height of the exposed surface of three plates. Plates generally a little wider than high, and ornamented with comparatively coarse, wide-spaced, raised lines, about six to 1 mm.

Distribution. The locality and horizon of the syntypes are Upper Ordovician, "Hudson River group" = Cincinnatian: Cincinnati, Ohio. Whether the range of the species should be considered more extensive is doubtful, as will appear from a discussion of the specimens hitherto assigned to it.

Material. The species was founded by Hall & Whitfield (1875) on two detached plates in the collection of U. P. James; of these syntypes, the original of their pl. iv, fig. 1 is hereby selected as Lectoholotype. To illustrate the complete shell of *Plumulites*, those authors reproduced, as their fig. 3, the drawing given by H. Woodward (1865) of *Turrilepas wrightiana*. The discovery of an apparently entire shell from the same horizon and locality enabled Faber (1886), who considered it and the specimen figured by S. A. Miller (1875) to be identical with the two syntypes of *Plumulites jamesi*, to show that it was distinct from *Plumulites*, and he thereupon founded the genus *Lepidocoleus*. Hall & Whitfield stated that they had detected plates apparently identical with the plates on which they founded the species, on surfaces of Trenton Limestone from Trenton Falls, New York, and in two papers by Dr. Ruedemann (1901) there are figured certain plates attributed to this species from the Trenton and Utica groups of various localities in New York State.

The British Museum contains five specimens assigned to this species, all from the E. O. Ulrich Coll., viz. In.17510, In.17511, and In.17512, from the Cincinnatian of Cincinnati, and In.17513, In.17514, from the Utica group of Covington, Ky.

Remarks. The British Museum material is not extensive enough to settle whether the plates from the Trenton and Utica groups are specifically identical with those from the Cincinnatian. The two plates from the Utica group (In.17513–14) certainly have the growth-lines finer and more close-set than have the three plates (In.17510, Pl. I, fig. 5, In.17511–12) from the Cincinnatian, and they are notably larger. In this connection it may be mentioned that Faber's specimen of *L. jamesi* measures only 12 mm. in length, and that one of the plates (In.17513) from the Utica group has a height of 4·1 mm. The specimens are too fragmentary to permit a comparison of the relative shape of the plates. The Cincinnatian plates are free from matrix, and on cleaning their inner surface more thoroughly, a deep muscle-scar was observed in all three plates.

Dr. Ruedemann's figures do not substantiate the specific identity of his fossils with *Lepidocoleus jamesi*, and in at least one instance the plate does not even belong to *Lepidocoleus*. His first paper (April, 1901) figures a plate (fig. 10) from the Trenton beds of Trenton Falls, New York, very like *L. jamesi*, and possibly that species. On the other hand, the plate (fig. 11) from Middle Trenton beds at Port Schuyler, Albany Co., New York, is a typical kite-shaped plate of *Plumulites* (s. str.) (see under *P. trentonensis* n. sp.). The remaining plate (fig. 12) from the Lower Utica beds of Mechanicsville, Saratoga Co., New York, may be a distal (terminal) plate of *Lepidocoleus jamesi*, but I am unable from the material seen by me to determine it as such. In his second paper (December, 1901) Dr. Ruedemann figures two plates from the Trenton Conglomerate of Rysedorph Hill, Rensselaer Co., New York. These differ notably in shape from the two plates (syntypes) of Hall & Whitfield, and in comparison with those plates are much longer and narrower. If oriented as left-hand plates of *Lepidocoleus* should be, with the umbo at the upper right hand, and the distal margin more or less horizontal, the plates are much wider in comparison to their height. Moreover, the fixed margin (or what would be the fixed margin in *Lepidocoleus*) is so obliquely inclined downwards and inwards from the umbo that the shape of the plates is altogether different, especially in Ruedemann's fig. 18.

Dr. Ruedemann describes in these plates some delicate lines crossing each other at right angles in the interspaces between the growth-lines, and in one case ending on them in slight beads. He states that the plates from the Utica group also show traces of this ornament, but says nothing as to the plates from the Cincinnatian. It is probable that other species would show this ornament if the plates were well preserved, for it can be seen in certain plates of *L. suecicus* in the British Museum, registered I.16020, I.16022 (Bather, 1914, p. 560).

Sufficient material from different horizons should enable one to judge as to the specific identity of the plates of *Lepidocoleus*

from the Trenton, Utica, Lorraine, and Cincinnatian, but, as shown above, one first has to be sure of the generic determination. In studying these forms it is well to bear in mind that other genera might exist, and the plates which appear at first to be so confusing may subsequently be quite easy to recognise. In *Lepidocoleus* comparison of the plates is much easier if they are oriented as nearly as possible in accordance with their position in the complete shell.

## *LEPIDOCOLEUS GRAYAE* Withers

(Plate I, figs. 7–10)

1908. Annelidan Tube (?), Reed, *Geol. Mag.* (dec. v), V, p. 295, pl. xii, figs. 9, 10.
1922. *Lepidocoleus grayae* Withers, *Ann. Mag. Nat. Hist.*, (9), IX, p. 654, pl. x, figs. 1–5.

Diagnosis. Shell with more than sixteen plates in a column, a length of more than 25 mm., and a breadth of 5 mm. equal to the height of the exposed surface of three plates; plates overlapping to almost half their height, mostly about twice as wide as high, with an ornament of comparatively wide-spaced growth-ridges, about four to a millimetre, and of five to six very slightly finer ridges between each main ridge, giving the surface, where well preserved, an exceedingly closely and regularly ridged appearance.

Distribution. Upper Ordovician, Ashgillian, Drummuck group, Mudstones: Thraive Glen, Girvan, Ayrshire.

Material. Two incomplete shells with the plates very little displaced, In.21648 and In.21649 (Mrs. Robt. Gray Coll.). Of these, In.21648 is the Holotype (Withers, 1922, pl. x, figs. 1–4).

Description. Specimen In.21649 (Pl. I, fig. 10) represents a shell, including the proximal extremity; its length is 20·4 mm., and its greatest breadth 5 mm. This shell is bent or humped, with the result that the plates are somewhat telescoped and displaced; the shell-layer of the plates has been removed in places, so that only the impression remains. At least sixteen plates or their impressions can be counted in serial order, but, owing to the bad preservation, the form of the plate at the base cannot be made out, although the rounded shiny impression on the matrix leaves no doubt that this really is the rounded basal extremity. Both this and the second shell show certain narrow longitudinal depressions, but these are evidently due to compression.

The holotype (Pl. I, figs. 7–9) was in two pieces, which fitted together quite readily. The larger piece shows a column of eight plates and an impression of another plate, and this is presumably the specimen represented by Reed (1908, pl. xii, fig. 9) in an inverted position, although it is not easily recognised from the figure. The smaller piece, which consists of two

columns, each of four plates, is evidently the third specimen mentioned by Reed. These two pieces, then, together comprise twelve plates and an impression of another in serial order, and these plates do not appear to have been displaced in any way, so the length of the shell, which measures 21·7 mm., is probably the correct length of the piece preserved, and its greatest breadth is 5 mm. On the other side of the shell the lowermost four plates are shown, but since they are much flattened, they do not show well on the broad "fixed" margin; but above these, in the middle of the specimen, the plates of the two series are seen to be in close apposition with little or no alteration. On this same side of the specimen, the lowermost three plates are broken away towards the narrow "free" margin, and, since the fourth plate is entire, one can measure the degree of overlap. The fourth plate has a breadth of 4·7 mm., and a height of 2·7 mm., and the third plate overlaps this to the extent of 1·2 mm., leaving 1·5 mm. exposed. The ornament of the plates consists of fine-growth ridges comparatively wide-spaced, numbering about four to a millimetre, and between these are from five to six slightly finer ridges, which give to the shell a peculiarly closely and regularly ridged appearance. Although the main ridges are clearly seen on both specimens, the finer ridges are well preserved only on this one, where they are very clearly shown on the lowermost four plates of the right-hand series; an enlarged view is given of the two lowest plates (Pl. I, fig. 9).

Comparison with other species. *L. grayae* is distinguished from other species by its exceedingly fine and numerous growth-ridges, but it appears to differ also from the known Ordovician and Silurian species in the relation of the length of the shell to the number of plates. *L. grayae* has at least sixteen plates to an incomplete shell, which would have measured at least 25 mm. *L. jamesi* (Hall & Whitfield), from the Hudson River group (Upper Ordovician) of Cincinnati, is said to have only fifteen plates in a complete shell, and this has only a length of about 12 mm., less than half the length of *L. grayae*. *L. sarlei* J. M. Clarke, from the Clinton group (Middle Silurian) of Rochester, New York, has thirteen plates to a complete shell, but this measures as much as 23 mm. *L. grayae* seems to be more nearly related to *L. squamatula* (Barrande), from the Upper Ordovician ($d^5$) of Bohemia, and *L. suecicus* Moberg, from the Upper Ordovician of Sweden—two species that appear to be very close indeed to each other. No shell approaching completeness is known of the two latter species, although a number of plates of *L. suecicus* have been found in association, but the plates appear to be in many instances higher in proportion to their breadth than is the case in *L. grayae*, and the growth-ridges number about seven to a millimetre, but without the intervening and almost equally prominent ridges seen in *L. grayae*.

## *LEPIDOCOLEUS STRICTUS* n. sp.

(Plate II, figs. 13, 14)

DIAGNOSIS. Shell with at least twenty-three plates in a column, and attaining a length of at least 17 mm., with a width of only 1·8 mm., equal to the height of the exposed surface of two to three plates. Plates probably more than twice as wide as high. Growth-lines indiscernible.

DISTRIBUTION. Lowest Silurian, Richmond group: Versailles, Indiana, U.S.A.

HOLOTYPE. The unique specimen I.7244, being the greater part of a shell (Pl. II, figs. 13, 14), (E. O. Ulrich Coll.).

DESCRIPTION. The specimen is entirely free from matrix and probably represents a shell with a few plates missing at each extremity. Viewed from either the fixed or free margin, the shell is of an elongated **S**-shape, and since no fracture is to be observed, the shape must be a natural one. The shell is very narrow for *Lepidocoleus*, its greatest width being only 1·8 mm., and the length of the portion preserved is 17·1 mm. There are as many as twenty-three plates, but the broken nature of the extremities indicates that there were more. The state of preservation leaves much to be desired, for it is difficult to see the shape of the plates, and impossible to see the growth-lines, but the plates seem to be more than twice as wide as high. On the fixed margin a slight alternation of the plates is apparent.

COMPARISON WITH OTHER SPECIES. Despite its poor preservation, the type-specimen is important, as yielding almost certain proof that *Lepidocoleus* was able to bend the shell in certain directions. It will be remembered that the holotype of *L. sigmoideus* (Pl. I, fig. 1) showed a sigmoid curve from the fixed to the free margin, but in this specimen the curve is from side to side of the shell. The present species differs from *L. sarlei* and *L. jamesi* in the greater number of plates, and from those and all the remaining species in the narrowness of the shell.

## *LEPIDOCOLEUS SARLEI* J. M. Clarke

(Plate IV, figs. 1–4)

1896. *Lepidocoleus sarlei* Clarke, *Amer. Geol.*, XVII, p. 140, pl. vii, figs. 1–6.
1910. *Lepidocoleus sarlei* Clarke: Grabau & Shimer, N. Amer. Index Foss., II, p. 371, fig. 1671.
1915. *Lepidocoleus sarlei* Clarke: Withers, *Geol. Mag.* (dec. vi), II, p. 114 (figs. 5 a, b), p. 121.

DIAGNOSIS. Shell with thirteen plates when complete, and a length of 23 mm.; width equal to the height of the exposed surface of from three to four plates.

DISTRIBUTION. Middle Silurian, Clinton group: Rochester, New York.

HOLOTYPE. The unique specimen figured by Clarke (1896).

DESCRIPTION. The holotype is a single shell with twelve plates on the right side and thirteen plates on the left. It apparently lacks only a single proximal plate on the right side, for there does not appear to be room for more than one plate. A very clear idea can be gained of the outer form of the shell from this really fine specimen.

At the distal end the terminal plate is acuminate, and that on the right side is smaller and is overlapped on the fixed margin by the somewhat larger terminal plate of the left side. The plates in this specimen evidently increase in height towards the distal end.

At the proximal end the basal plate on the left side is comparatively large and semicircular, and it is probable that in the complete shell there was a similar but smaller plate on the right side.

The plates of the two columns show strong alternation, and the proximal extremity of the shell is fairly strongly bent towards the free margin. No details of the ornament have been given.

COMPARISON WITH OTHER SPECIES. *L. sarlei* appears to differ from all other species in which the shell is at all complete by its small number of plates, and especially the relation of this number to the length of the shell.

## *LEPIDOCOLEUS REINHARDI* Ruedemann

(Text-fig. 2)

1925. *Lepidocoleus reinhardi* Ruedemann, *Bull. N.Y. State Mus.*, No. 265, p. 76, pl. xxiii, fig. 5.

DIAGNOSIS. Shell with more than eighteen (probably twenty-one) plates to a length of 60 mm. Width 10 mm., equal to the height of the exposed surface of three plates. Ornament not discernible.

DISTRIBUTION. Middle Silurian (Ontarian), Bertie Waterlime group: Williamsville, near Buffalo, New York.

HOLOTYPE. The unique specimen in the New York State Museum (Reinhard Coll.).

DESCRIPTION. The specimen consists of an internal cast exposing the left side, the distal part of which has been broken away, leaving an impression of the right side. Since the specimen is merely a cast of the inner surface, no details are known of the ornament, nor can the degree of overlap of the individual plates be measured. Ruedemann mentions, however, that a muscle-scar, represented by a small subcircular elevation, can be detected near the middle of each of the larger plates preserved at the proximal end of the shell.

Both extremities of the shell are bent towards the back or fixed margin, so that the shell resembles a boomerang in shape, with the convexity on the free margin. The fixed and free

margins are fairly parallel, with a slight contraction towards the bluntly rounded proximal end, and a gradual one towards the acutely triangular terminal or distal plate.

The number of plates to a column is more than eighteen, and probably as much as twenty-one, to a length of 60 mm. The width of the shell is 10 mm., equal to the height of the exposed surface of three plates, and the width of each plate is three times the height of the exposed surface.

Of the shape of the plates Ruedemann says, " The posterior margins of the plates are sigmoidally flexed, in basal direction on the dorsal or ' fixed ' side and more strongly in apical direction on the ventral [' free '] side. The flexed plate is apparently not completely preserved. The impression of the

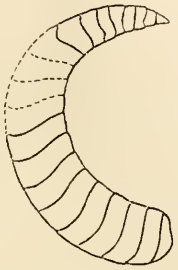


Fig. 2.—*Lepidocoleus reinhardi* Ruedemann. Holotype. Nat. size. (After Ruedemann.) Middle Silurian (Ontarian), Bertie Waterlime: Williamsville, near Buffalo, N.Y., U.S.A.

plates is concave along the ventral margin, gently convex upon the middle, and sharply convex and bent down on the dorsal side, giving the impression that the plates may have possessed considerable thickness and been thinner along the ventral margins."

Comparison with other species. The shell of this species is much larger than any except that of *L. sigmoideus* from the Middle Ordovician (Trenton) of Ontario, Canada. The holotype of *L. sigmoideus* is 64 mm. long, and has at least fifty-five plates to a column, probably sixty when complete, and the width (6·5 mm.) of the shell is equal to the height of the exposed surface of seven plates. *L. reinhardi*, therefore, while agreeing closely in length (60 mm.), has less than half the number of plates to a column (more than eighteen, and probably twenty-one). While the width of *L. reinhardi* is comparatively greater (10 mm.), it is equal only to the height of the exposed surface of three plates, instead of seven as in *L. sigmoideus*.

## *LEPIDOCOLEUS KETLEYANUS* (Reed ex Salter MS.)

(Plate III, figs. 1–10)

1871. *Ateleocystites huxleyi* Billings = *Placocystites forbesianus* de Koninck: Woodward, *Geol. Mag.* (dec. i), VIII, p. 72, figs. 6 a–c (non figs. 1–5, 7).

1873. *Ateleocystites fletcheri* Salter = *Placocystites forbesianus* de Koninck: Morris in Salter, Cat. Camb. Sil. Foss., Cambridge, Addenda, p. xlvii (Woodward's figures reproduced).

1873. *Turrilepas ketleyanus* Salter sp. MS. (*nom. nud.*): *op. cit.*, p. 129 (*b* 730).

1880. *Ateleocystites* (*Placocystites*) *forbesianus* (de Koninck): Woodward, *Geol. Mag.* (dec. ii), VII, p. 197 (figures reproduced).

1892. *Turrilepas ketleyanus* Salter (*nom. nud.*): Woods, Cat. Type Foss., Cambridge, p. 132.

1901, March. *Turrilepas* ? ? *ketleyanus* Salter: F. R. C. Reed, *Geol. Mag.* (dec. iv), VIII, p. 108.

Diagnosis. Shell with at least thirty-five plates in a column, and attaining a length of at least 32 mm., and a width of about 4 mm. Plates shaped like a saddle-flap, transversely oblong and convex, nearly three times as wide as high; fixed margin straight; free margin rounded; distal margin almost straight, but with slight sigmoid curve; proximal margin concave in the middle and convex at the sides. Ornament: exceedingly fine, close-set, but not raised, lines, concentric in the apical region, and then parallel to the free margin; not always readily discernible.

Distribution. Middle Silurian, Lower Salopian, Wenlock Beds: Dudley, Worcestershire.

Material. Of the two syntypes of *Turrilepas* ? ? *ketleyanus* Reed, the specimen here first figured (Pl. III, fig. 1), which shows well the shape and ornament of the plates, is selected as Lectoholotype. Both specimens are in the Sedgwick Museum, Cambridge (No. 220). In the British Museum are thirty-one specimens, registered 59058, I.540, I.16255–I.16271, I.16293–I.16301, I.16307, In.17508, In.17509. The species is therefore fairly common.

History. The name *Turrilepas ketleyanus*, unsupported by either description or figure, first appeared in Salter's "Catalogue" (1873, p. 129), with a reference, added by either Cookson or J. Morris, who after Salter's death in 1869 prepared his MS. for the press, to "b. 730, Dudley (Mr. Ketley)." Morris also (*loc. cit.*) gave a definition of *Turrilepas*, based on Woodward (1865) and *T. wrightiana* (de Koninck), and stated that "Salter considered it an Annelide tube . . . and proposed the name *Oploscolex* for it." This statement, it will be seen, affords no grounds for including *Oploscolex* among the synonyms of *Lepidocoleus*.

The validation of the specific name is due to Dr. Cowper Reed, who described the two specimens in the Woodwardian (now Sedgwick) Museum to which Salter's name was attached

as "*Turrilepas* ?? *ketleyanus* Salter," and remarked (March, 1901, pp. 108–9) : "The two original specimens are very poorly preserved and fragmentary, and the plates seem to be displaced from their original position, and the description, therefore, is far from satisfactory. . . . It is extremely doubtful if this fossil is the remains of a crustacean, and it has been suggested with much probability that it represents the column of one of the Anomalocystidae. The supposed shape of the plates in the double row cannot be regarded as of much value, owing to their imperfect condition. It is unfortunate that Salter chose to attach a specific name to such exceedingly unsatisfactory specimens."

Fortunately, though the plates are displaced from their original positions, the two specimens are by no means so unsatisfactory as they at first appear. Although Dr. Cowper Reed's description was written when he was evidently quite unaware of the generic position of these fossils, it was his description of the plates that suggested the identity of his species with a form from the Wenlock Beds of Dudley, well represented in the British Museum. This suggestion was confirmed when, by the kindness of Mr. Henry Woods of the Sedgwick Museum, the two original specimens were sent for comparison with those in the British Museum. It also became clear that they represented a species of *Lepidocoleus*, for some of the British Museum specimens are nearly complete, and their plates are identical in shape and ornament with the specimen (In.17508) figured by Dr. H. Woodward (1871, p. 72, figs. 6 a–c) as a stem of the Cystid *Placocystites forbesianus* de Koninck.

Description. Of the two syntypes, one shows five plates in position on a piece of shale, with two displaced plates touching their base. To the left of these, as well as below, are to be seen two pairs of juxtaposed plates. The lecto-holotype (Pl. III, fig. 1) has a larger number of plates, scattered about on a piece of shale. The general shape of the plates is well shown, and under a lens the delicate ornament is to be seen on certain of them. Apart, therefore, from the shape and ornament of the plates, the type-specimens give very little idea as to the length of the complete shell or the total number of plates.

Specimen 59058 (Pl. III, fig. 3) is rather flattened laterally, and the ornament of the plates badly preserved, but it gives a good idea of the length and form of the shell. It appears to be somewhat incomplete at its distal end; thence to the base there are as many as thirty-five plates occupying a length of 32·2 mm. Since the plates are badly preserved and somewhat telescoped into one another, it is rather difficult to count them, but the number is more rather than less. The base of the specimen is evidently broken, but close alongside the left of the specimen, at the base, there are some displaced plates, which almost certainly belong to the same shell. Of these there are at least

ten, so that, allowing five for each side of the shell, the number of plates in the complete shell would be forty. Adding 4 mm. for the height of the exposed portion of the five plates, we get a length of shell of 36·2 mm. The greatest breadth appears to be about 4·1 mm.

Specimen I.540 (Pl. III, fig. 8) shows a shell in which all the plates are slightly displaced, although keeping more or less the general shape of the shell. This has a length of just 40 mm., but the displacement of the plates prevents one from taking this measurement as very exact.

A smaller specimen, I.16307 (Pl. III, fig. 4), looks as if it were complete, but if so it would appear to have a smaller number of plates than has the original of Pl. III, fig. 3. It is difficult to distinguish the individual plates in the distal part of the specimen, but the total number preserved is probably about twenty-five. The rounded-off appearance of the distal end is, however, very likely to be deceptive, in which case the shell is incomplete. At its proximal end the shell appears to be terminated by a semicircular plate. The interest of this specimen lies in the fact that the shell is curved like a boomerang, with the concavity on the free margin.

In none of the above specimens is it possible to distinguish well the plates of either the distal or proximal extremities, but specimen I.16264 (Pl. III, fig. 2) appears to show the proximal termination of the shell. Here the plates of the distal incomplete part of the shell are crushed together, and the proximal part of the shell upturned and laid at the right side of the crushed portion. If the last plate visible in this portion really is the basal plate, then that plate is semicircular, just as in *Lepidocoleus sarlei*, and as appears to be the case in specimen I.16307 (Pl. III, fig. 4). The uncrushed plates in the present specimen show that they overlapped from below to about one-fourth of their height, and this feature is also shown in the specimen next described.

That specimen (In.17508) is the only one which shows the back of the shell at all well and uncrushed (Pl. III, figs. 5–7). It was originally figured by Dr. H. Woodward (1871, text-figs. 6 a–c) as " probably the lower extremity of the stem " of the Cystid *Placocystites forbesianus* de Koninck. This fragment, which is from about the middle of the shell, consists of twelve plates on each side, and has a length of 11·2 mm. On the back the comparatively deep groove formed by the infolding of the plates is well shown, and the plates show little or no alteration. The specimen, especially if viewed from the free margin, shows a slight sigmoid curve.

The separate plates of *L. ketleyanus* are shaped like a saddle-flap. They are transversely oblong and convex, nearly three times as wide as high, with the proximal and distal margins subparallel; distal margin straight to slightly curved sigmoidally; proximal margin concave in the middle and convex at the sides;

fixed margin slightly convex, with a small part inwardly bent; free margin broadly rounded. Towards each end of the shell the fixed and free margins of the plates converge towards each other, so that the plates differ slightly in shape.

The ornament consists of exceedingly fine, close-set, but not raised lines, concentric in the region of the umbo, and then parallel to the free margin (Pl. III, fig. 9). In many of the plates the fine lines cannot be seen. The minute pits and granulations mentioned by Dr. Cowper Reed appear to be due to the presence of minute particles of shale adhering to the test. On the inner surface (Pl. III, fig. 10) each plate is slightly bevelled along the proximal margin, probably to avoid a projecting edge on the inside of the shell, such as would otherwise be caused by the overlap of the plates. Close up against the inturned fixed margin there is a well-marked scar. This is not rounded but rather angular at the top, and has the appearance of an inverted **V** obliquely inclined towards the umbo.

Comparison with other species. With the exception of *L. sigmoideus* and *L. reinhardi*, *Lepidocoleus ketleyanus* probably attained a greater length than any of the Ordovician and Silurian species, and, excepting *L. strictus* n. sp., it is very much narrower than any of them. It differs also in the narrowness of the plates vertically, in their shape, and in the exceedingly fine, close-set, but not raised lines. *L. strictus* n. sp. is more like it than any other species, but its shell is much narrower, and the height of the plates relative to their width is greater; it is unlikely that it attained either the length or the plate-number (about thirty-five) of *L. ketleyanus*. *L. sigmoideus* is the only species having a larger number of plates (probably sixty).

## *LEPIDOCOLEUS BRITANNICUS* n. sp.

(Plate II, figs. 10–12)

Diagnosis. Shell with probably twenty-five plates in a column, and attaining a length of about 35 mm., and a width of about 5 mm. Plates transversely convex, nearly one and a half times as wide as high; distal and fixed margins straight; free margin slightly convex, and the angle formed by it with the proximal margin sharply to broadly rounded; proximal margin slightly concave near the back. Ornament: well-marked, fine, raised lines, comparatively wide-spaced (six to 1 mm.) following the outline of the proximal and free margins.

Distribution. Middle Silurian, Lower Salopian, Wenlock Beds: Malvern, Worcestershire.

Holotype. The nearly complete unique specimen I.5032, (Pl. II, figs. 10–12), (H. B. Holl Coll.).

Description. The specimen shows the left side uppermost (fig. 10) as well as the back (fig. 11); the upper and lower extremities are absent. Thirteen plates are in position in its

distal region, the upper edge of the distalmost plate just appearing beneath that of the preceding plate. At the base of these connected plates, and almost at right angles to the free margin of the shell, lies a further group of seven somewhat broken plates. From their position, and from their following the other plates quite naturally, it cannot be doubted that they belong to the same individual. There could not have been more than one or two additional plates at the distal end, and, although the broken condition of the plates at the base makes it difficult to judge, it seems probable that the total number of plates did not greatly exceed twenty-five. As the specimen lies, the length of the upper group of thirteen plates is about 22 mm., and of the lower group of seven plates, 8·4 mm. To judge from these measurements, the length of the complete shell must have been about 35 mm. Its greatest breadth is 5·3 mm.

On the back (Pl. II, fig. 11) the apices of the more distal plates have been worn away, but the more proximal plates appear to alternate slightly. The height of the exposed portion slightly varies with the individual plates, probably because the shell was shifted after the death of the animal. The average amount of plate showing is about 1·5 mm. (= about ·43 of the height of the plate). In no case is it possible to see the whole of a plate, but the third plate from the base shows about 3 mm., the complete height of the plate being probably 3·5 mm. The width of a plate near the middle is 5·3 mm.

It is difficult to estimate the shape of the plates, but the distal and fixed margins are almost straight, the free margin slightly convex, and the angle formed by it with the proximal margin is sharply rounded in the more distal plates, but more obtusely in the more proximal plates.

The raised growth-lines are fine, comparatively wide-spaced (six to 1 mm.), and well marked, but, especially near the free margin, there are faint intervening ridges parallel to the main growth-lines. Owing to the amount of plate exposed, the transverse as well as the vertical portions of the growth-lines are visible for more than half the width of the plates.

Comparison with other species. This fine species reminds one of *L. sarlei* J. M. Clarke, from the Middle Silurian (Clinton group) of New York. The holotype of that species is of about the same width as *L. britannicus*; but it has only thirteen plates, with a total length of 23 mm., whereas our species had certainly twenty, and probably twenty-five plates, and a total length of about 35 mm. when complete. No good figure of the ornament in *L. sarlei* has been published. *L. jamesi* from the Ordovician of Cincinnati is said to have fifteen plates to the complete shell, its length being about half that of *L. sarlei*. The growth-lines in our species, although finer, are about as wide-spaced as in *L. jamesi*, but are more wide-spaced than in the Ordovician species, *L. suecicus* and *L. squamatula*.

## *LEPIDOCOLEUS POLYPETALUS* J. M. Clarke

(Plate IV, figs. 5–6)

1896. *Lepidocoleus polypetalus* Clarke, *Amer. Geol.*, XVII, p. 142, pl. vii, figs. 7, 8.

Diagnosis. Shell (incomplete) with seventeen plates in a column, and a length of 35 mm., width equal to the height of the exposed surface of four plates.

Distribution. Lower Devonian, Lower Helderberg group: Albany Co., New York.

Holotype. Unique specimen in New York State Museum.

Description. This species is known by a single incomplete shell broken at the proximal and distal extremities. There are seventeen plates in the left column, and the incomplete shell has a length of 35 mm. As the shell is somewhat obliquely crushed, only part of the left side is exposed for the greater length of the shell, the back being on the under side of the specimen, and is only partly free from matrix. Three plates at the distal end retain their convexity; these appear to show that the plates overlapped each other to quite half of their height, and that the growth-lines form a broad convex curve following the outline of the convex proximal and free margins. The shell shows a slight basal curvature, but it is not well-marked.

Comparison with other species. See under *L. latus* n. sp.

## *LEPIDOCOLEUS ILLINOIENSIS* Savage

(Plate IV, figs. 7–9)

1913. *Lepidocoleus illinoiensis* Savage, *Amer. Journ. Sci.*, (4), XXXV, p. 149, text-figs. 1–3.

Diagnosis. Shell (incomplete) with seventeen plates in a column and a length of 33 mm.; width equal to the height of the exposed surface of three to four plates. Ornament: fine, thread-like lines.

Distribution. Lower Devonian, Upper Oriskany (Clear Creek chert): Union Co., Illinois.

Holotype. A unique specimen, presumably at the University of Illinois.

Remarks. Although incomplete at the distal and proximal extremities, the holotype, which is preserved in the form of a cast in chert, has seventeen plates in the left column and thirteen in the right, the part preserved measuring 33 mm. The plates show strong alternation, they overlap each other for one-half or more of their height, and are ornamented with "fine, thread-like lines" which run parallel to the proximal and free margins. Proximal margin convex; free margin straight. Owing to compression, the edges of the plates of the right column have been pushed beyond those of the left on the free margin, thus showing more clearly than in most specimens that it was along this margin that the shell opened.

Comparison with other species. See under *L. latus* n. sp.

## *LEPIDOCOLEUS LATUS* n. sp.

(Plate IV, figs. 10, 11)

DIAGNOSIS. Shell (incomplete) with twenty-three plates in a column, a length of 26 mm., and a width of 6·7 mm., equal to the height of the exposed surface of six plates.

DISTRIBUTION. Middle Devonian: near Olomouc, Moravia, Cecho-slovakia.

HOLOTYPE. The unique specimen (Pl. IV, figs. 10, 11) in the collection of Dr. M. Remeš, Olomouc.

DESCRIPTION. Shell entirely free from matrix, incomplete at the distal and proximal extremities, with twenty-three plates in each column in the piece preserved. Length 26 mm., width 6·7 mm. Viewed from the left side the shell shows sigmoidal curvature, the proximal extremity being markedly curved away from the free margin, and the distal extremity slightly towards it. The plates of the two columns show little or no alternation. Height of exposed portion of each plate 1·1 mm., and the width consequently slightly exceeds the height of the exposed portion of six plates. The shell has been so much worn that it is not easy to make out the ornament, or even the form of the plates, but the plates must have overlapped to more than half of their height.

REMARKS. Although represented only by a single ill-preserved shell, which does not show very clearly the shape or ornament of the individual plates, *L. latus* is an important fossil. It is not only the only known Middle Devonian species of *Lepidocoleus*, but since the two remaining Devonian species, *L. polypetalus* J. M. Clarke and *L. illinoiensis* Savage, come from the Lower Devonian of North America, it is the only Devonian species known outside that country. The specimen is further important as showing distinct crystalline cleavage.

From *L. polypetalus* and *L. illinoiensis* the shell differs in being proportionally much wider, in having a narrower portion of each plate exposed, and in the greater number of plates in proportion to the length of shell. In other words, *L. latus* has twenty-three plates to a length of 26 mm., and the width of the shell is equal to the height of the exposed surface of six plates; in *L. polypetalus* there are seventeen plates to a length of 35 mm., and the width of the shell is equal to the height of the exposed surface of four plates; in *L. illinoiensis* there are seventeen plates to a length of 33 mm., and the width of the shell is equal to the height of the exposed surface of from three to four plates. *L. illinoiensis* is said by its author to differ from *L. polypetalus* "in being somewhat smaller and in tapering less rapidly from below upward. The plates also are less convex and more uniformly curved than those figured by Dr. Clarke." This goes to show that the two American species closely resemble one another.

## *Species known only from detached plates*

### *LEPIDOCOLEUS SUECICUS* Moberg

(Plate II, figs. 1–5)

1914, July. *Lepidocoleus suecicus* J. C. Moberg, *Kgl. Fysiogr. Sällsk. Handl.*, N.F., XXVI, No. 1, p. 13, pl. ii, figs. 1–11.
1914, Nov. *Lepidocoleus suecicus* Moberg: J. C. Moberg, *Geol. Fören. Stockholm Förhandl.*, XXXVI, Hft. vi, p. 489.
1918. *Lepidocoleus suecicus* Moberg: G. T. Troedsson, *Kgl. Fysiogr. Sällsk. Handl.*, N.F., XXX, No. 3, p. 46.

Diagnosis. Plates normally with height and width approximately equal (between 3 mm. and 5 mm.), but in others the height exceeds the width; distal margin slightly to moderately concave; fixed margin convex; proximal margin usually strongly sigmoidal; free margin either making with the distal margin a broadly rounded angle of 90° or more, or converging towards the apex. Growth-lines comparatively wide-spaced (about seven to 1 mm.), fine, flat, with a tendency near the distal margin to turn inwards to the apex.

#### *Swedish Specimens*

Distribution. Upper Ordovician, Black Trinucleus Shales: Ullnäs and Örberga, Ostergötland; Amtjärn, Enån, Fjecka, Gulleråsens Skräddaregård, Svälasgård near Skattungbyn, and Wikarbyn, Dalecarlia. Brachiopod Shales: Röstanga and Tommarp, Scania.

Material. From among the syntypes of Moberg I here fix as lecto-holotype the specimen from Svälasgård described by him (July, 1914, p. 15), and here figured Pl. II, fig. 1 (I.14425, colld. Dr. F. A. Bather).

In addition to the lecto-holotype, there are in the British Museum five single plates from Ullnäs, registered I.16018–I.16022, and these, having been presented by Prof. Moberg from among his syntypes, now rank as paratypes.

Description. The lecto-holotype consists of a piece of shale with the impression of fifteen or more plates evidently representing the proximal part of a shell of a single individual. Three plates of the left side, near the middle of the specimen, are in their natural serial position, but the others of the left and right side are displaced, and two plates show enough of their inner surface to expose the muscle-scar.

The five detached plates have the shell itself preserved, and this is highly crystalline and shows distinct cleavage. In some specimens the growth-lines project slightly on the distal margin, giving that margin a serrated edge, and there is a distinct tendency in these plates for the growth-lines to become crowded towards the free margin. Two of the plates (I.16020, I.16022) show delicate lines crossing each other at right angles in the interspaces between the growth-lines.

Four plates seen by Prof. Moberg show a muscle-scar on their inner surface.

*British Specimens*

DISTRIBUTION. Upper Ordovician. Ashgillian: *Phacops mucronatus* beds of Lake District, Lancashire, and Yorkshire; Shoalshook Limestone of Haverfordwest. Caradocian: Coniston Limestone series—Applethwaite Beds and Dufton Shales of Lake District; Upper *Dicranograptus* or Mydrim Shales of Haverfordwest (*Orthis argentea* beds). The detailed localities are given under the next heading.

MATERIAL. British Museum: six specimens, mostly of single plates, collected and presented by Professor J. E. Marr, F.R.S., viz.

*P. mucronatus* beds, Nanny Lane, Troutbeck, Windermere, In.23973 (Pl. II, fig. 2).

*P. mucronatus* beds, Odgill, Cautley, Yorksh. In.23967.

*Orthoceras vagans* (= Lower *mucronatus*) beds, 200 yards N.E. of Boo Tarn, S. of Timley Knott, Lancs. In.23968–23970.

Applethwaite Beds, Garbourn Road, Troutbeck, Windermere. In.23971, specimen with counterpart, having four or five plates in series.

Sedgwick Museum, Cambridge: twenty-nine specimens, mostly single plates, some in counterpart as indicated by the hyphenated numbers.

*P. mucronatus* beds, colld. J. E. Marr: Pull Beck, No. 46 (Pl. II, fig. 3); Troutbeck Hundreds, No. 45; near Nanny Lane, Troutbeck, No. 47.

Shoalshook Limestone, Shoalshook Ry. cutting, Haverfordwest, colld. V. M. Turnbull, Tablet 113, 3778 (Pl. II, fig. 5).

Dufton Shales (Horizons 3, 4, 5), Alston Road, Melmerby, Cumberland, colld. V. M. Turnbull, Tablet 84, 2461–2, 2463, 2464–5, 2466; Tablet 85, 2665–6; Tablet 86, 2459.

Mydrim Shales, colld. V. M. Turnbull: Prendergast Lane, Haverfordwest, Tablet 69, 96 a–b; Tablet 70, 97 a–b; Tablet 71, 1411–12; 1501, 1502, 1507–8; Tablet 89, 1413–14, 1415, 1503–4, 1505–6, 1509–10, 1511–12, 3026–7, 3028–9; Spittal Road Cutting ?, Treffgarne, Haverfordwest, Tablet 108, 4068–9; Tablet 109, 4076–7; Tablet 110, 4074–5; Tablet 111, 4072–3; Tablet 112, 4070–1 (Pl. II, fig. 4).

DESCRIPTION. Some of these plates are those which Dr. Cowper Reed referred to *Turrilepas* (1908, pp. 523, 525). The two plates from Windermere (Pl. II, figs. 2, 3), and those from Boo Tarn, Lancs., have the shell preserved, and this is highly crystalline and shows definite cleavage. One specimen

(In.23968) has two plates showing a muscle-scar on their inner surface. The remaining specimens consist almost entirely of single plates of which the shell itself has been dissolved; in most cases the specimen is represented by an imprint of the outer surface, while its counterpart, if present, bears an imprint of the inner surface, and these are best studied by means of squeezes taken from the natural moulds. On the imprint of the inner surface of two plates (Sedgwick, 1411, 1504) a very fine reticular ornament is seen. As many as twenty-one specimens show the inner surface or its imprint, and it is important to note that, without any exception, all show a muscle-scar; this is the case in every plate of *Lepidocoleus* of which I have seen the inner surface.

Comparison with other species. *L. suecicus* is evidently close to *L. squamatula* Barrande, but judging from the small number of plates of *L. squamatula* at my disposal, it seems advisable at present to keep them apart. One of the plates of *L. squamatula* is higher than wide, but in this plate there is no tendency for the free margin to curve inwards towards the apex as it does in the high plates of *L. suecicus*. In *L. suecicus* the growth-lines are flatter, finer, and wider apart. How far this is due to compression is not clear, but it is the fact that the Swedish plates of *L. suecicus* are much flattened and that the plates of *L. squamatula* retain their convexity.

The plates from the Lake District agree very well with the Swedish plates but seem to have a slightly thicker shell. The remaining British Ordovician plates come from various horizons and localities, and it may be that their slight differences in aspect are due to the varying conditions of the deposits in which they are found and to their different preservation. Some of them are slightly distorted. Possibly more than one species is represented, but more perfect material will have to be collected before anything further can be done.

## *LEPIDOCOLEUS SQUAMATULA* (Barrande)

(Plate II, fig. 9)

1872. *Plumulites squamatula* Barrande, Syst. Sil. Bohême, I, Suppl., p. 576, pl. xx, fig. 22 (? fig. 23, ? non fig. 24, from e 1, Borek).
1914. *Lepidocoleus squamatula* (Barrande): Moberg, *Geol. Fören. Stockholm Förhandl.*, XXXVI, p. 492.
1915. *Lepidocoleus squamatula* (Barrande): Withers, *Geol. Mag.* (dec. vi), II, p. 121.

Diagnosis. Plates with height and width approximately equal (between 3 and 4 mm.); distal margin almost straight; fixed margin convex; proximal margin slightly convex to slightly sigmoidal, and making with the free margin a broadly rounded angle of 90° or more. Growth-lines close-set (seven to ten to 1 mm.), and comparatively coarse and raised.

Distribution. Upper Ordovician (d 5): Mt. Kosow, Bohemia.

MATERIAL. In the Bohemian Museum, Prague, the syntypes of Barrande. In the British Museum, four detached plates, In.17504–In.17507. These four plates are accompanied by one of Barrande's original labels, which reads "*Squamula bohemica* Barr. D-. Mt. Kosow." As already written in a preliminary paper (Withers, March 1915, p. 121): "Barrande states in his Monograph that in 1856 certain fossils were distributed to the British Museum under the generic names *Plumulites*, *Anatifopsis*, and *Squamula*. He later, however, considered that there were two generic types only, not feeling justified in retaining the proposed genus *Squamula*. The above four specimens are therefore some of those which he originally intended to include in *Squamula*, and they appear to be identical with the plates figured by him (1872, p. 576, pl. xx, figs. 22–24, especially fig. 22) as *Plumulites squamatula*, a species recorded from Étages D and E. Their reference to *Plumulites* was probably the reason for giving up *Squamula*, but that genus would have been quite justified, since *Plumulites squamatula* undoubtedly belongs to the genus *Lepidocoleus* C. L. Faber (1887). Meanwhile the name *Squamula* has no nomenclatorial validity."

While the paper just quoted was going through the press, there appeared Prof. Moberg's second paper (Nov. 1914), in which he also referred *Plumulites squamatula* to the genus *Lepidocoleus*. Prof. Moberg was of the opinion (p. 492) that the plates figured by Barrande represented more than one species, and said that *P. squamatula* (pars) had to be placed among the synonyms of *Lepidocoleus suecicus* Moberg. He considered Barrande's fig. 22 (from d 5, Mt. Kosow) to be distinct from *L. suecicus*, but was uncertain where to place fig. 23 (also from d 5, Mt. Kosow). Fig. 24 (from e 1, Borek) he regarded as most readily identifiable with *L. suecicus*. Unfortunately Prof. Moberg transposed the horizons of figs. 22 and 24. The original of fig. 24 is actually from the Silurian, and since it shows certain differences from the Ordovician *L. suecicus*, it may not be the same species.

In any case, as previously claimed by Moberg (1914) and Withers (1915), Barrande's figures of *Plumulites squamatula* doubtless represent more than one species, and to save any likely confusion the original of Barrande's fig. 22 (from d 5) is hereby selected as the Holotype of *P. squamatula*. This leaves the original of fig. 24 (from e 1) free to be regarded as an example of *L. suecicus* by those who accept the identity, without making that name a possible synonym of *P. squamatula*.

MEASUREMENTS. Three specimens have the following measurements:

| No. | Height in mm. | Width in mm. |
|---|---|---|
| In.17504 (Pl. II, f. 9) | 3·2 | 3·3 |
| In.17505 | 3·9 | 3·1 |
| In.17506 | 3·6 | 3·7 |

Description. All four plates (In.17504–7) appear to show the true convexity of the shell, for they have not undergone any flattening during fossilisation. One of them (In.17507) has been cut into sections for microscopical examination, leaving only three plates intact. The main characters of the outer surface have been given rather fully in the diagnosis. The distinguishing features of the plates seem to be the closeness and coarseness of the growth-lines and the very slight sigmoidal curvature of the proximal margin. One plate (In.17506), accompanied by an imprint of the inner surface, shows a well-marked scar or pit. The scar is rounded and situated near the middle of the plate, rather nearer to the broad margin. A close examination of this plate shows on its broken edges distinct crystalline cleavage, characteristic of calcite and Echinoderm stereom. On the matrix from which the plate was taken is to be observed a fine reticular ornament, which is very distinctly seen on the inner surface of the plate.

Comparison with other species. *L. squamatula* seems most like *L. suecicus* Moberg, especially as regards the ratio height : width of the plates. It differs, not only in the coarseness and closeness of the growth-lines, but also in the less pronounced sigmoidal curvature of the proximal margin. Moreover, the free margin, and consequently the growth-lines, do not turn inwards towards the apex at their distal (outer) extremities, as they do in several of the plates of *L. suecicus*.

*L. jamesi* differs in the more widely-spaced growth-lines, in the relatively greater width of the plates, and in their smaller size.

## *LEPIDOCOLEUS TURNBULLI* n. sp.

(Plate II, fig. 6)

1907. *Turrilepas* sp. : Reed, *Geol. Mag.* (dec. v), IV, p. 537; list name.
1908, Dec. ? *Turrilepas peachi* Nich. & Eth. : Reed, *Trans. R. Soc. Edinburgh*, XLVI, p. 523.

Diagnosis. Plates broader than high; distal margin almost straight; fixed margin hardly at all convex; proximal margin strongly sigmoidal; fixed margin somewhat curved outwards. Growth-lines very close-set (about ten to 1 mm.), fine and raised.

Distribution. Lower Silurian, Lower Valentian, Haverford Stage (Lower Llandovery), lower part of Cartlett Beds with *Diplograptus* (*Mesograptus*) *modestus*, St. Martin's Mudstone of Reed (1907) : roadside near St. Martin's Cemetery, Haverfordwest. See Mem. Geol. Surv. England & Wales, Geol. S. Wales Coalfield, pt. xi, Sheet 228, Haverfordwest, 1914, especially p. 101.

Material. Sedgwick Museum, Cambridge, seven plates, Nos. 1839, 1941–2, 1943; Tablet No. 75, 1946–7; Tablet No. 76, 1944–5, 2701–2; Tablet No. 76 a, 2703–4 (V. M. Turnbull Coll.).

Of these No. 1839 is the Holotype, and the figure Pl. II, fig. 6, is from a squeeze of its natural mould or imprint.

Description. Of the seven plates, five have counterparts, and all are in the form of moulds of the outer or inner surface, the shell itself having been dissolved. Four specimens, 1941–2, 1946–7, 2701–2, 2703–4, show the inner surface and each has the characteristic muscle-scar. Three specimens have the following measurements :

| No. | Length in mm. | Breadth in mm. |
|---|---|---|
| 1839 | 3·6 | 4 |
| 2701–2 | 3·5 | 3·7 |
| 2703–4 | 2·5 | 2·7 |

Comparison with other species. This form agrees quite closely with *L. birmanicus*, but has the growth-lines a little more close-set; and parallel to the proximal margin they are much more strongly sigmoidal, even in the region of the apex. In view of this it seems inadvisable to refer these plates to *L. birmanicus*. Both forms differ much from the remaining Silurian species and approach more nearly the Ordovician species, such as *L. suecicus*.

## *LEPIDOCOLEUS BIRMANICUS* n. sp.

(Plate II, figs. 7, 8)

1915. *Turrilepas* sp. : Reed, *Pal. Indica*, n.s., VI, Mem. No. 1, p. 86.

Diagnosis. Plates broader than high; distal margin almost straight; fixed margin convex; proximal and free margins forming together almost a continuous wide curve; free margin curved outwards. Growth-lines close-set (eight to ten to 1 mm.), fine and raised.

Distribution. Lower Silurian, Panghsa-pye Beds (= Llandovery) : Panghsa-pye, Northern Shan States, Burma.

Material. Two pieces of shaly and apparently non-calcareous rock (marked K.11·95), one in the Sedgwick Museum, and the other in the British Museum (In.18383, Pl. II, fig. 7), both bearing scattered imprints of several plates. These form part of the original material described by Dr. Cowper Reed, and were presented by the Geological Survey of India. A plate on the Sedgwick Museum specimen is the Holotype, and Pl. II, fig. 8, is from a squeeze of its natural mould.

Description. Most of the plates are incomplete and consist of moulds of the outer surface, but on the Sedgwick Museum specimen one of the imprints is of the inner surface and has the characteristic muscle-scar. The holotype plate has a height of 2 mm., and a breadth of 2·8 mm. The remaining characters are given under the diagnosis.

Comparison with other species. *L. birmanicus* much resembles the British Lower Silurian species *L. turnbulli*. The growth-lines are not quite so close-set, and differ further in that

they are so slightly sigmoidal parallel to the proximal margin as to form almost a continuous curve, as in fact they do completely in the region of the apex.

## Family *TURRILEPADIDAE*

Diagnosis. Machaeridia in which the shell has four columns of strongly imbricating subtriangular plates, those of the inner or admedian columns being keeled, and those of the outer columns being kite-shaped.

The genera certainly to be referred to this family are *Turrilepas*, *Plumulites*, and *Deltacoleus*.

History. In 1865, Dr. H. Woodward founded the genus *Turrilepas* for a fossil from the Wenlock Shale of Dudley, originally described as a *Chiton* by De Koninck (1857) under the name *C. wrightianus*. Woodward considered this fossil to be a Cirripede allied to *Loricula* [= *Stramentum*], and, although he did not give a generic diagnosis, he illustrated the form by several figures.

In 1872, Barrande described and figured several species of similar fossils from the Ordovician and Silurian rocks of Bohemia, and for them he founded a new genus *Plumulites*. He had observed these fossils so early as 1846, and in 1856 distributed some of them among certain collections, notably that of the British Museum, under his MS. generic name *Plumulites*. A. Reuss, having seen the most perfect of the specimens of *Plumulites bohemicus* in the Barrande collection, considered these fossils to be the remains of Cirripedes allied to *Loricula*, and took occasion to point this out in 1864 at a meeting of the Imperial Academy of Science of Vienna. Although Reuss recorded the name *Plumulites* in his paper (1864, p. 215, note 2) published the same year, he gave neither description nor figure, so that no definition or figure of *Plumulites* was published until Barrande gave both in 1872. Notwithstanding this, Barrande, on the plea of previous publication, claimed priority for *Plumulites* over the genus *Turrilepas*, which was founded and illustrated by Dr. Woodward in 1865. After a few years there followed a discussion by various authors as to the claims of one name over the other. Hall & Whitfield (1875) adopted *Plumulites*, but Hall & J. M. Clarke (1888) gave preference to *Turrilepas*, and the views of Nicholson & Etheridge, jun. (1880) were quoted by Dr. Woodward (1889) in favour of his own name *Turrilepas*. Among later authors, some gave priority to *Plumulites* and others to *Turrilepas*, but, except for G. F. Matthew (1896) and Cowper Reed (1908), who ventured to raise a doubt on this point, all agreed that these two names referred to the same genus. They have also been regarded as synonyms in the text-books.

An investigation of the structure of the fossils referred to

*Turrilepas* (genotype *T. wrightiana*) by H. Woodward, and to *Plumulites* (genotype *P. bohemicus*) by Barrande, led to the conclusion that they were distinct genera, and just as this was being embodied in a preliminary paper on the Palaeozoic fossils referred to the Cirripedia (Withers, March, 1915) Prof. J. C. Moberg (July, 1914) came to the same conclusion, and in his paper distinguished between these two genera. He added very little to our knowledge of their structure, gave no generic diagnoses, but in a general discussion pointed out the differences observable in the published figures. These figures, as we now know, give a wrong idea of the structure of both *Turrilepas* and *Plumulites*, and although the separation of these two genera by Prof. Moberg and myself is abundantly justified, the real difference lies more in the form of the plates than in their arrangement.

## Genus TURRILEPAS H. Woodward

1857. *Chiton* Linn. (*partim*) : L. G. de Koninck, *Bull. Acad. Sci. Belgique*, (2), III, p. 199; transl. 1860, *Ann. Mag. Nat. Hist.*, (3), VI, p. 97.
1865. *Turrilepas :* Woodward, *Quart. Journ. Geol. Soc.*, XXI, p. 486.
1865. *Turrilepas* Woodward : Salter & Woodward, Chart Foss. Crustacea, p. 26.
1873. *Oploscolex* J. W. Salter MS. : *cit.* Morris as Editor, Salter, Cat. Camb. Sil. Foss. Cambridge, p. 129, as syn. of *Turrilepas*.
1877. *Turrilepas :* Woodward, Brit. Mus. Cat. Brit. Foss. Crustacea, p. 143.
1890. *Turrilepas* Woodward : Etheridge, jun., *Geol. Mag.* (dec. iii), VII, p. 337 (*partim*).
1892. *Turrilepas* Woodward : Aurivillius, *Bihang Svenska Vet.-Akad. Handl.*, XVIII, Afd. iv, No. 3, p. 20.
1914. *Turrilepas* Woodward : Moberg, *Kgl. Fysiogr. Sällsk. Handl.*, N.F., XXVI, No. 1, p. 19.
1915. *Turrilepas* Woodward : Withers, *Geol. Mag.* (dec. vi), II, p. 122.

Diagnosis. Shell of triangular cross-section, the median plates keeled, obtusely triangular, somewhat saddle-shaped, the outer or kite-shaped plates flat, without longitudinal folds, obliquely and obtusely triangular. Proximal or basal plate roughly forming a right-angled triangle.

Genotype. *Turrilepas wrightiana* (de Koninck), which is the only named species of the genus as here defined. A single keeled plate from the Silurian of New South Wales has been described by R. Etheridge, jun. (1890), as *Turrilepas* sp.

History. In first describing this fossil as *Chiton wrightianus*, De Koninck (1857) based his observations on two detached plates on a piece of Wenlock Shale from Dudley, Worcestershire. Although, even in his figure, the plates are asymmetrical, he included them in a restoration of a *Chiton*, with a unilinear series of eight symmetrical plates.

H. Woodward (1865) gave a new figure of the holotype, and pointed out the asymmetrical form of the plates as one of his

arguments against their reference to a *Chiton*. Besides the holotype, Woodward figured five more or less complete individuals, but his examination of these did not allow him to arrive at any definite opinion as to their precise structure. This is especially the case with regard to the number of columns, for he states (p. 487): "*Chiton wrightianus* had probably as many as four rows of plates," and further (p. 489), "As to the number of rows of plates . . . Mr. Ketley's specimen seems to require two rows of large plates to complete its circumference." Since this specimen displays two rows of keeled plates, and on either side a row of kite-shaped plates, this addition would make six rows of plates. Further on (p. 489), however, he writes: "It is probable that the two broad rows of intersecting [keeled] plates corresponded with the lateral rows of plates, and the two minute rows [the kite-shaped plates] with the carinal and rostral series along which the specimen seems more readily to have divided, as in the case of *Loricula*." Consequently, if there were an opposing series of so-called "minute" plates and of the keeled plates, the number of rows would be eight.

It will be gathered, therefore, from Woodward's paper that he was uncertain as to the number of rows of plates. It is usually given as four to six. The number of plates in a vertical row was said to be eleven in one specimen, and in another fifteen. The animal's shell was compared with the Cretaceous Cirripede *Stramentum* [= *Loricula*], and since Woodward stated that the opercular [? capitular] plates were unknown, it has been generally held that he considered his specimens to represent the peduncular part of the shell. This is emphasised by his words (p. 488): "the plates have their overlapping points directed upwards, or towards what I believe to have been the aperture of the shell."

Subsequent authors apparently have based their conception of *T. wrightiana* on Woodward's figure 1 h, and this has been reproduced in many papers and in palaeontological text-books. Unfortunately this figure has led to quite an erroneous idea of the generic structure, and the specimen on which it is based represents only about the proximal half of an individual. Of this figure J. M. Clarke (1896) has written: "This specimen indicates an elongate strobile-shaped body constituted of overlapping subtriangular plates arranged in not less than four vertical rows, in two of which the plates are of much larger size than the others." The views of Clarke and others, in fact, show that the idea of *Turrilepas wrightiana* conveyed by Woodward was of a cone-shaped body composed of not less than four, and as many as eight, rows of overlapping plates, with the aperture of the shell at the top. Prof. Gruvel (1905), however, has given a curious figure, adapted from Woodward's figure (1 h), in which there are ten rows of plates, five rows on each side, forming a laterally flattened shell, as in *Loricula*.

A study of I.16272, the original of Woodward's figure 1 h (Pl. V, figs. 3–4), led me to consider that none of these conceptions of *Turrilepas wrightiana* could be correct, and this has been borne out by a detailed examination of the available material. Of the inner structure of the shell, and its relation to the soft parts, nothing has up till now been known.

Structure. There are four columns of plates, namely, two median columns of keeled plates, and on each side an outer column of flat, kite-shaped plates, the four columns arranged to form an elongate blade-shaped shell, which allows of no additional columns. The number of plates in a column is as many as thirty.

Each plate is distinctly asymmetrical, but the kite-shaped plates correspond in shape and size with the plates in the opposing series; this is also true of the keeled plates, except that those of the right side have a wider admedian portion owing to the different position of the longitudinal fold. Only a part of each plate is exposed, for each plate overlaps the succeeding one by from one-half to two-thirds its height. The keeled plates of the two series are subtriangular and somewhat saddle-shaped, but the sides of the left series are less broadly rounded; their apices lie next the broad back. The kite-shaped plates are flat, not attenuated, and have no longitudinal fold.

The broad and almost flat back is formed by the admedian portion of the keeled plates, bounded by the longitudinal fold, and the sides are formed by the side face of the keeled plates and the outer kite-shaped plates. The keeled plates of the two columns alternate regularly with each other, and since the admedian part of the right series of plates is slightly wider, the plates do not alternate medially but about one-third the distance from the left side. On each side the keeled plates are intersected by the kite-shaped plates.

Along the free margin the plates are only in loose apposition, and it is along this margin that the shell opened. The shell tapers gradually towards each extremity, and to allow of this there is a gradual reduction in size of the plates. Except for this reduction there is no modification of the plates at the distal end. At the proximal end there is a plate on the left side, in series with the keeled plates, but differing from them in shape and in the direction of growth-lines. In outline it is roughly that of a right-angled triangle, having a short convex base with which the growth-lines are parallel, and the whole plate is strongly convex, following the direction of the growth-lines. The short base probably lay towards the side of the shell, and to some extent overlapped the somewhat flat keeled plate above, as well as the base of the corresponding proximal plate on the right side of the shell. The apices of the proximal pair of plates were probably directed slightly downwards and towards the middle

line of the back, so as to form a more or less acute median termination to the base of the shell.

Both extremities of the shell are frequently bent towards the fixed margin, and it may be that the animal was capable of straightening or otherwise changing its shape. A scar in each keeled plate, close up against the longitudinal fold, looks like a pit for the attachment of a muscle, by which such movement may have been effected.

Nothing has been known hitherto of the inner structure of the shell in *Turrilepas*, and its relations to the soft parts. Removal of the matrix from three keeled plates of the left series, and three keeled plates of the right, showed that each plate had a muscle-scar (Pl. VI, figs. 5–7), similar to that in *Lepidocoleus*. It is evident that all the keeled plates had such a muscle-scar and that the two rows of keeled plates were in close apposition.

In brief, we arrive at the conclusion, which is well supported by the structure of the shell, that *Turrilepas* has a blade-shaped shell composed of four columns of alternating plates, that the shell opened along the narrow margin formed by the meeting of the kite-shaped plates, and that the soft parts were attached by a muscle to each of the plates comprising the two keeled series. The shell had as many as thirty plates in a column and attained a length of at least 60 mm.

## *TURRILEPAS WRIGHTIANA* (de Koninck)

(Plate V, figs. 1–6; Plate VI, figs. 1–8)

1857. *Chiton wrightianus* de Koninck, *Bull. Acad. Sci. Belgique*, (2), III, p. 199, pl. i, figs. 2 a–c; transl. *Ann. Mag. Nat. Hist.*, (3), VI, p. 97, pl. ii, figs. 2 a–c.

1865, Sept. *Turrilepas wrightii* H. Woodw. [*sic*]: Salter & Woodward, Chart. Foss. Crustacea, p. 26, figs. 1–3 (figures reproduced in a notice of the work, *Geol. Mag.*, Oct. 1865, p. 470).

1865, Nov. *Turrilepas* (*Chiton*) *wrightii* H. W. [*sic*]: Woodward, *Quart. Journ. Geol. Soc.*, XXI, p. 489, pl. xiv, figs. 1 a–l.

1866. *Turrilepas wrightii* H. Woodw.: Woodward, *Rep. Brit. Assoc.* (for 1865), p. 321, figs. 1–3.

1873. *Turrilepas wrightianus* (de Koninck): J. W. Salter, Cat. Camb. Sil Foss. Cambridge, p. 129, text-fig.

1877. *Turrilepas wrightii* H. Woodw.: Woodward, Brit. Mus. Cat. Brit. Foss. Crustacea, p. 143.

1877. *Turrilepas wrightii* H. Woodw.: Woodward, Encyclop. Britannica, 9th ed., VI, p. 666, fig. 86.

1896. *Turrilepas wrightiana* (de Koninck): Clarke, *Amer. Geol.*, XVII, p. 137, pl. vii, fig. 10.

1914. *Turrilepas wrightiana* (de Koninck): Moberg, *Kgl. Fysiogr. Sällsk. Handl.*, N.F., XXVI, No. 1, p. 19, pl. i, figs. 4–6, pl. ii, fig. 23.

1915. *Turrilepas wrightiana* (de Koninck): Withers, *Geol. Mag.* (dec. vi), II, p. 122, text-figs. 7 a, b (p. 114).

1920. *Turrilepas wrightiana* (de Koninck): Withers, *Ann. Mag. Nat. Hist.*, (9), V, p. 80, figs. 1 a, a′.

1908. non *Plumulites wrightii* (H. Woodw.): Stepanov, *Verhandl. russ. miner. Ges.*, (2), XLVI, p. 197, pl. ii, fig. 16.

This being the only known species of the genus, no specific diagnosis can be given.

Distribution. Middle Silurian, Lower Salopian, Wenlock Beds: all British specimens are from Dudley except one from Malvern (I.16308), Worcestershire. Bed *d* of Lindström, at various localities on I. of Gotland, Sweden (Aurivillius, 1892, p. 20).

Material. The Holotype is the original specimen figured by de Koninck as *Chiton wrightianus*, and later by H. Woodward (figs. 1 a, b), formerly in the collection of John Gray of Hagley, and presented by him in 1865 to the British Museum, I.16283 (Pl. VI, fig. 4).

Besides the holotype, two only of the six specimens figured by Woodward (1865, pl. xiv, figs. 1 g, 1 h) have been available for study, and these also are in the British Museum, viz. 59057 (Allport Coll.) and I.16272 (H. Johnson Coll.). The three remaining specimens cannot be traced. Of these the original of fig. 1 e–f was in the collection of Mr. Charles Ketley, but Prof. W. S. Boulton kindly states that this specimen is not in the Ketley collection now in the possession of Birmingham University. The originals of figs. 1 c, 1 d, were in the E. J. Hollier collection, but Prof. J. W. Carr has kindly searched and failed to find them in the Hollier collection now in the Natural History Museum of University College, Nottingham. Mr. Henry Woods has also failed to find any of these three specimens in the Sedgwick Museum, Cambridge.

Other specimens in the British Museum are the following:

Seven nearly complete shells, viz. 59056 (Pl. VI, fig. 3), Allport Coll.; 47871 (Pl. V, fig. 6, Pl. VI, fig. 1), 59406 (Pl. V, fig. 5), and 59164 (Pl. V, figs. 1, 2), Ketley Coll.; I.16282, J. Gray Coll., 1889; I.16277, I.16280, H. Johnson Coll., 1886.

Four keeled plates, viz. In.25812 (Pl. VI, fig. 5), In.25813 (Pl. VI, fig. 6), In.25814 (Pl. VI, fig. 7), and In.25815, all presd. T. H. Withers, 1925.

One kite-shaped plate from Malvern, I.16308 (Pl. VI, fig. 8), Holl Coll.

On the preceding twelve specimens, in addition to the type-material, the present description of the species is based.

Two shells with two or more rows of plates exposed, viz. 46429, Ketley Coll.; I.16306, Old Coll.

Twenty-three specimens consisting of scattered plates, of which most are single keeled plates, viz. 46433, I.16286–I.16292, Ketley Coll.; I.16273–I.16276, I.16278, I.16279, Johnson Coll.; I.16284, I.16285, J. Gray Coll. 1865; I.16281, J. Gray Coll. 1889; I.4420, G. H. Morton Coll., 1900; I.16254, purchd. Gregory, 1884; I.16302–16305, Old Coll.

The Museum of Practical Geology has nine specimens:

Eight show keeled plates only, viz. 28272, 28274–28280. One

(28273) shows keeled and kite-shaped plates in association, and one of the keeled plates displays a muscle-scar.

The Sedgwick Museum, Cambridge, has one specimen, a single keeled plate, No. 241 (J. F. Walker Coll.).

These make a total of fifty British specimens noted.

Description. During fossilisation the shells have been subjected to pressure on the sides, and owing to their triangular cross-section, and to the weakness caused by the shell opening along the free margin, one or other of the sides has usually been forced beyond the other. This feature is well shown in Pl. V, figs. 1–2, 3–4; the specimens figured have been flattened so that they show both the left side and the back of the shell. One of these (H. Woodward's fig. 1 h) is free from matrix, and we see on its other side (Pl. V, fig. 4) the outer half of the right-hand series of keeled plates and of the right-hand kite-shaped plates, and the inner surface of the left-hand plates. Although the right-hand kite-shaped plates are not figured in the other specimen (Pl. I, figs. 1–2), they have been developed in its proximal part not seen in the figure. Other specimens show one side of the shell only; thus those figured in Pl. V, fig. 5, Pl. VI, fig. 3, show the left side, while that figured in Pl. VI, fig. 2, shows the right side. It is probable, however, that at the death of the animal the shell sometimes gaped, for in one specimen (Pl. V, fig. 6, Pl. VI, fig. 1) all four rows of plates are spread out; in this specimen only the proximal part of the shell is preserved.

Apparently the shell was somewhat bent back upon itself like a scimitar, for in five of the seven specimens which approach completeness, the extremities are curved towards the back (see Pl. V, figs. 1, 3–4, & 5). Two specimens (Pl. VI, figs. 2, 3), it is true, do not show this feature, but they are not so complete. Evidently the plates were capable of movement upon one another, and it may be that, while the shell was ordinarily curved towards the back, the animal was capable of straightening it or otherwise changing its shape. The scar in the outer portion of each keeled plate, close up against the longitudinal fold, looks like a pit for the attachment of a muscle, by which such movement may have been effected.

The plates imbricate from below, and to judge from the specimens, especially those figured in Pl. V, figs. 1–2, 3–4, 5, the degree of overlap is at least one-half, if not two-thirds the height of the plate.

Specimen 59164 (Pl. V, fig. 1), except for the fact that several of the plates are broken, is almost certainly a complete shell. It shows that the shell tapers gradually towards each extremity, and that, to allow of this, there is a gradual reduction in size of the plates, especially in the width of the admedian portion, so that the plates along the back converge towards each end.

At the distal end of the shell, except for the reduction in

size, there does not appear to have been any modification in the general structure of the plates. In specimen 59164 (Pl. V, fig. 1) the kite-shaped plates are broken away here, but the bluntly rounded form of the apical part seems to show that it is almost, if not quite, complete.

At the proximal end of 59164 there is a portion of a plate in series with the keeled plates but differing from the others in the direction of the growth-lines. It proved possible, though with considerable trouble, to expose a perfect example (Pl. VI, fig. 1) of this plate at the base of specimen 47871 (Pl. V, fig. 6), which has the four rows of plates spread out. This plate undoubtedly forms the proximal termination of the shell, and it agrees not only in shape, but in the direction of its growth-lines, with the broken plate observed in specimen 59164 (Pl. V, figs. 1–2). This proves that the proximal portion of that specimen is complete. Both these plates are on the left side, and a similar plate probably occurred on the right side, though it has not yet been observed. The outline of this proximal plate is roughly that of a right-angled triangle, the right angle being contained by a long straight side and a short convexly rounded base; the third (hypoteneuse) is also convexly curved. The growth-lines are parallel to the convex base, but near the straight side they are rather abruptly bent downwards. The whole plate is strongly convex, following the direction of the growth-lines. The position of the left proximal plate appears to have been such that its convex base lay towards the side of the shell and to some extent overlapped the somewhat flat keeled plate above as well as the base of the corresponding proximal plate on the right side of the shell. The apices of the proximal pair of plates were probably directed slightly downwards and towards the middle line of the back, so as to form a more or less acute median termination to the base of the shell.

The number of keeled plates in a longitudinal series, including the proximal plate, is as many as thirty in the supposed complete specimen 59164 (Pl. V, fig. 1), but since the plates are somewhat telescoped into one another at the upper part of the specimen, it is difficult to count them. Specimen 59406 (Pl. V, fig. 5), which is not quite complete at its extremities, has twenty-seven plates in a series. Specimen 59057 (Pl. VI, fig. 2), the original of Woodward's figure 1 g, has twenty plates in a series. Specimen I.16272 (Pl. V, figs. 3–4), the original of Woodward's figure 1 h, has hitherto been regarded as complete, but has only thirteen plates in a series, and represents only about half a shell, probably lacking only the proximal plate to make it complete at its proximal extremity.

The shape of the keeled plates differs in the two series, mainly owing to the difference in position of the longitudinal fold. The back of the shell is formed by the overlapping and alterna-

tion of the admedian portion of these plates, bounded on each side by the longitudinal fold of the plates. It is best shown in specimen 59164 (Pl. V, fig. 1), and since the longitudinal fold is further removed from the admedian margin of the right series of plates, a greater width of the admedian portion of that series goes to form the back of the shell. In consequence the plates do not alternate medially, but about one-third the distance from the left side.

Although the general position of the plates is well shown in the more complete specimens, and especially in the incomplete specimen 47871 (Pl. V, fig. 6), their general shape and structure is best studied from the disconnected plates. The holotype, I.16283 (Pl. VI, fig. 4), shows two keeled plates, a left at the top and a right below, but it is not certain that they belong to the same individual. The left plate is 9·6 mm. wide, and 8·3 mm. in height, and has the longitudinal fold situated about one-third the distance from the admedian margin. The right plate is 11·3 mm. wide, and about 8·2 mm. in height, and the longitudinal fold is nearly median, but slightly nearer to the admedian margin. Consequently the plates have a much broader and more rounded proximal margin to the admedian portion than have the plates of the left series. Both plates are subtriangular, but the sides of the plates of the left series make a more acute angle. The proximal margin is somewhat similar in both plates, being strongly rounded below the admedian portion, curving upwards beneath the longitudinal fold, from which it makes a sinuous curve ending in the broadly rounded outer margin. The raised ridges are more strongly marked where they curve over the longitudinal fold.

In some well-preserved plates of the keeled series, the upper margin of the admedian portion is denticulated, and this is the case even between the slight prominences formed by the projection of the raised ridges. The denticulation is well shown at the base of specimen 59164 (Pl. V, fig. 2).

A well-marked scar (? muscle pit) is to be observed on the inner surface of the left and right series of keeled plates. Three plates, two right (Pl. VI, figs. 5, 7) and one left (Pl. VI, fig. 6), are figured. These figures show that the muscle-pit is comparatively deep, and is situated about half-way from the apex close up against the longitudinal fold, the plate being somewhat thickened above. Six of these plates, taken at random, were cleaned altogether, three left and three right, and a muscle-pit was found in each.

The outer or kite-shaped plates appear to agree in shape in the two series, although they are not too well preserved in any of the specimens. Perhaps the more perfect are shown in position in specimen 47871 (Pl. V, fig. 6), and a very fine disconnected example (I.16308) from the right side is shown on

Pl. VI, fig. 8. In shape it resembles somewhat the kite-shaped plates in *Plumulites*, but the apical half is not so attenuated and the typical longitudinal fold is absent. The outer surface is flat, and the inner surface, like that of the keeled plates, shows a fine reticular structure. The distal margin is markedly concave near the apex, the remainder of the margin being straight. The outer margin sweeps down from the apex and with the proximal margin forms almost a semicircle, except that the middle of the proximal margin is slightly indented. In width (along the distal margin) the plate measures 9·2 mm., and in height (from the distal to the proximal margin) 5·1 mm. The shell is excessively thin, much thinner than in the keeled plates, and this is no doubt the reason why these plates are so frequently broken and ill-preserved. These kite-shaped plates are disposed between the lateral or outer portion of each keeled plate, and overlap the keeled plates to such an extent that their base extends almost, if not quite, up to the longitudinal fold. Their outer margin consequently extends very little beyond the outer margin of the keeled plates. Their normal position is apparently exhibited in specimen I.16272 (Pl. V, figs. 3, 4) which shows the inner surface of the left side of the shell.

Ornament.—The outer surface of each keeled and kite-shaped plate is marked with regular, equi-distant, elevated lines concentric with the base, probably terminating a period of growth, the distance apart being usually 0·4 mm. in the larger plates. The proximal plate is similarly ornamented except that the lines are closer together.

Measurement. At least a length of 60 mm. must have been attained by this species, for one of the specimens (Pl. V, fig. 5), if measured from the complete distal part to the lowest left median plate, which we know does not complete the proximal extremity, measures quite 57 mm. A right median plate and two right kite-shaped plates are displaced in this specimen and extend below the lowest left keeled plate, but these are not included in the measurement. Its greatest width, near the middle, is 10·9 mm.

## *TURRILEPAS* sp.

1890. *Turrilepas* sp., R. Etheridge, jun., *Geol. Mag.* (dec. iii), VII, p. 338, pl. xi, fig. 3.

Distribution. ? Wenlockian, Bowning Beds, Lower Trilobite Bed : Bowning Creek, New South Wales.

Material. The original specimen was in the collection of Mr. John Mitchell.

Remarks. This is undoubtedly a right keeled plate similar to that in *T. wrightiana*, but, without an examination of the specimen, it is impossible to say whether it is specifically the

same. This plate is of much interest, for *Turrilepas*, as here defined, is otherwise known only from the Middle Silurian of England and Sweden. At Bowning Creek it is found in association with a species of *Plumulites*, *P. mitchelli*, which was described by Etheridge under the genus *Turrilepas* H. Woodward (see p. 69).

## Genus DELTACOLEUS n.g.

(δέλτα, Δ shape; κολεός, sheath.)

Diagnosis. Shell of triangular cross-section, the median plates subtriangular, keeled or angularly bent along a submedian line from the apex and rectangularly produced below, the outer plates almost flat, without a median longitudinal ridge, approaching in shape an acute-angled isosceles triangle, and with the outer proximal angle broadly rounded.

### *DELTACOLEUS CRASSUS* n. sp.

(Plate VIII, figs. 6–8)

1879. *Turrilepas scotica* R. Etheridge, jun.: Nicholson & Etheridge, Silur. Foss. Girvan, p. 214, pl. xiv, fig. 25.
1908. *Turrilepas scotica* R. Etheridge, jun.: Reed, *Trans. Roy. Soc. Edinburgh*, XLVI, pp. 524–5, plate, figs. 6 (? *T. scotica*), 13.
?1914. *Plumulites* ?: Moberg, *Kgl. Fysiogr. Sällsk. Handl.*, N.F., XXVI, No. 1, p. 18, pl. ii, fig. 21.

This being the only known species of the genus, no specific diagnosis can be given.

Distribution. Upper Ordovician, Caradocian, Balclatchie group: Balclatchie, and Dow Hill, Girvan, Ayrshire. Middle Ordovician, Llandeilian, Barr series, Stinchar Limestone: Aldons, Girvan, Ayrshire.

Material. Two median plates (In.23708, from Balclatchie; In.23673, from Dow Hill) and three outer plates (In.23735, In.23736–7) from Aldons (Mrs. Robt. Gray Coll.). As Holotype is taken the median plate, In.23708 (Pl. VIII, fig. 7).

One of the two median plates was figured by Nicholson & Etheridge, jun. (1879, pl. xiv, fig. 25), and by Reed (1908, fig. 13), as *Turrilepas scotica*, and the other was figured by Reed (1908, fig. 6) as *Turrilepas* sp., and doubtfully referred in the text (p. 525) to *T. scotica*. Except that they occur in the same beds with *Plumulites scoticus*, there seems no reason for referring them to that species.

Description. The holotype (Pl. VIII, fig. 7), from Balclatchie, is roughly triangular, has a thick calcareous shell, and a strong submedian fold along which the two sides of the shell are bent almost at right angles to each other. The much larger plate (Pl. VIII, fig. 6), from Dow Hill, is essentially the same kind

of plate. Its shell is not preserved, and the specimen is in the condition of a natural cast of the inner surface, the imperfect counterpart being a mould of the outer surface. This latter plate has been described fully by Reed (1908, p. 525).

Apart from the fact that the shell, as shown by the smaller plate, is very much thicker than in *P. scoticus*, the general shape of the plates differs so much from the median plates of *Plumulites*, especially in the more angulated proximal angles, that they cannot be confidently referred to that genus, let alone to the species *P. scoticus*. They differ just as much from the obtusely triangular median plates of *Turrilepas*. The plates evidently belong to a form somewhat intermediate between *Turrilepas* and *Plumulites*, but closer to *Turrilepas*. Such angularly bent plates as these, which Dr. Cowper Reed agrees belong to the median series, and in fact they could not belong elsewhere, must have formed part of a blade-shaped shell, triangular in transverse section.

Whether the outer plates from Aldons (see Pl. VIII, fig. 8) belong to this same form is a point that cannot be definitely decided, more especially since they do not come from the same horizon. What is clear, however, is that these plates differ from the outer plates of *Plumulites* in the absence of a longitudinal fold, and from the outer plates of *Turrilepas* in being of a much more erect shape, for the outer plates of *Turrilepas* are obliquely and obtusely triangular. An outer plate precisely similar in shape to those from Aldons, Girvan, was figured as *Plumulites*? by Moberg (1914, July, p. 18, pl. ii, fig. 21) from the Upper Silurian (*colonus* shales) of Röddinge, Scania, but it is not certain that it is conspecific with the Girvan form.

It seems requisite, therefore, to recognise that these plates represent a new form, rather than to obscure this fact by referring them even doubtfully to *P. scoticus*, and for this reason a new genus is instituted, although the possibility is recognised that these two types of plates may afterwards be found to belong to more than one species.

## Genus PLUMULITES Barrande

1864. *Plumulites* (ex Barrande MS.), Reuss, *Sitz. Akad. Wiss. Wien*, XLIX, p. 215 (note 2), (name only).
1872. *Plumulites* Barrande, Syst. Sil. Bohême, I, Suppl., p. 565.
1878. *Turrilepas* H. Woodward : R. Etheridge, jun., *Proc. R. Phys. Soc. Edinb.*, IV, p. 164.
1880. *Turrilepas* H. Woodward : Nicholson & Etheridge, Silur. Foss. Girvan, p. 213.
1888. *Turrilepas* H. Woodward : Hall & Clarke, Palaeont. New York, VII, pp. lxiii, 215.
1889. *Turrilepas* H. Woodward : Woodward, *Geol. Mag.* (dec. iii), VI, p. 272.
1890. *Turrilepas* H. Woodward (*partim*) : Etheridge, *Geol. Mag.* (dec. iii), VII, p. 33.

1908. *Turrilepas* H. Woodward (*partim*) : Reed, *Trans. Roy. Soc. Edinb.*, XLVI, pt. iii, p. 519.
1910. *Turrilepas* H. Woodward : Chapman, *Proc. Roy. Soc. Victoria*, n.s. XXII, p. 105.
1914. *Plumulites* Barrande : Moberg, *Kgl. Fysiogr. Sällsk. Handl.*, N.F., XXVI, No. 1, p. 5.
1915. *Plumulites* Barrande : Withers, *Geol. Mag.* (dec. vi), II, p. 122.
1921. *Plumulites* Barrande : Withers, *Ann. Mag. Nat. Hist.* (9), VIII, p. 124.

Diagnosis. Shell of triangular cross-section, the median plates keeled and heart-shaped, the outer or kite-shaped plates somewhat flattened, acuminate, with a strong, narrow, submedian, longitudinal fold, and a similar but narrower fold near to the distal margin. Proximal or basal plates with the apex broadly rounded, the umbo a little removed from the apex, and the growth-lines forming concentric rings round it.

Genolectotype. *Plumulites bohemicus* Barrande.

Species and distribution. Since the history of *Plumulites* is so bound up with that of *Turrilepas*, the main facts have already been given under the latter genus (see p. 33). Although Barrande based his generic diagnosis mainly on the species *Plumulites bohemicus*, he included in the genus a number of other species. To remove any doubt regarding the genotype, I here definitely fix on *P. bohemicus*. Some such action is necessary, since Barrande (1872) included in *Plumulites* at least two genera, namely, *Plumulites* (s. str.), represented by the nine species *P. bohemicus*, *P. compar*, *P. contrarius*, *P. delicatus*, *P. discretus*, *P. folliculum*, *P. fraternus*, *P. minimus*, and *P. regius*, and *Lepidocoleus*, to which genus *P. squamatula* has been referred (see p. 29). Of these species, *P. bohemicus* and *P. folliculum* are the more important, and are dealt with more fully in this Catalogue.

Other species of *Plumulites* have been described by various authors under either *Turrilepas* or *Plumulites*, and of these by far the most complete is *P. peachi* Nich. & Eth., from Girvan. The better preserved, including the new species *P. trentonensis* and *P. llanvirnensis*, are fully discussed in the following pages and others are dealt with under " Doubtful Species " (p. 71).

This leaves the plates mentioned or described by Dr. Cowper Reed (1908, pp. 523, 525) from the Upper Ordovician of Haverfordwest and the Lake District, and referred by him to *Turrilepas*. Through the kindness of Prof. Marr, Dr. Cowper Reed, and Mr. Henry Woods, all these specimens in the Sedgwick Museum, Cambridge, were sent to me on loan, as well as others from the same localities that were received after the publication of Dr. Cowper Reed's paper. Examination of all the specimens, seventy in number, shows that the genus *Turrilepas* is unrepresented, for about half belong to the genus *Lepidocoleus* (*antea*, pp. 28, 31) and the remainder to *Plumulites* (p. 56).

The distribution of the species of *Plumulites* may be tabulated as follows :—

| | | | |
|---|---|---|---|
| Middle Devonian. | *P. devonicus* Clarke (1882). Hamilton group, Ontario Co., N.Y. | | |
| Lower Devonian. | | | |
| Upper Silurian. | | *P.* sp. (*P. haswelli* Salter MS.). Upper Ludlow, Pentland Hills. | |
| Middle Silurian. | *P. gracillimus* Ringueberg (1888). Clinton group, Rochester Shales, Lockport, N.Y. | | *P.* sp. Stepanov (1908). Wenlockian, W. Siberia.<br>*P. mitchelli* (Eth., 1890). Bowning Beds, N.S. Wales.<br>*P. ornatus* (Chapman), 1910. Melbournian, Victoria.<br>*P. yeringiae* Chapman (1910). Yeringian, Victoria. |
| Lower Silurian. | | ? *P. peachi* (Nich. & Eth.), 1880. Saugh Hill group, Girvan. | *P. delicatus* Barr. (1872).<br>*P. discretus* Barr. (1872). Both e 2, Bohemia.<br>*P. minimus* Barr. (1872). e 1, Bohemia.<br>*P. pygmaeus* Moberg (1914).<br>*P. rastritum* Moberg (1914). Both Rastrites Shales, Sweden. |
| Upper Ordovician. | | *P. peachi* (Nich. & Eth.), 1880. Whitehouse & Drummuck groups, Girvan. *Staurocephalus* Beds, Lake District. Redhill Beds & Shoalshook Lst., Haverfordwest. Dufton Shales, Cumberland.<br>*P. scoticus* Eth. (1878). Balclatchie group, Girvan. | *P. regius* Barr. (1872). d 5, Bohemia.<br>*P. törnquisti* Moberg (1914).<br>*P. dalecarlicus* Moberg (1914). Both Black Trinucleus Shales, Sweden. |
| Middle Ordovician. | *P. canadensis* (H. Woodw.) (1889). Top of Trenton group, Ottawa, Canada.<br>*P. trentonensis* n. sp. Trenton group, Albany Co., N.Y. | | *P. fraternus* Barr. (1872). d 3, 4, Bohemia.<br>*P. regius* Barr. (1872). d 3, Bohemia.<br>*P. esthonicus* Withers (1921). Kuckers Stage, Esthonia. |
| Lower Ordovician. | *P. mobergi* T. H. Clark (1924). Lévis Shales, Quebec. | *P. llanvirnensis* n. sp. Lower Llanvirn series, Pembrokeshire. | *P. folliculum* Barr. (1872). d 2, Bohemia.<br>*P. bohemicus* Barr. (1872). d 1, Bohemia.<br>*P. compar* Barr. (1872). d 1, Bohemia.<br>*P. contrarius* Barr. (1872). d 1, Bohemia.<br>*P. regius* Barr. (1872). d 1, Bohemia. |

Structure. As with *Turrilepas*, our present knowledge of the structure of *Plumulites*, though not very definite, affords no justification for assuming that the columns of plates in the shell numbered more than four or that they formed a cone-shaped body. Although uncertain as to the precise relation of the plates to each other, Barrande (1872) showed that they were in four vertical columns. He figured the two types of plates forming the four columns, as well as the "cancellated plate" which he supposed to come from the base or proximal end of

the shell. In all the specimens which approach completeness, the plates of the four columns are spread out, and this has evidently led to the statement by Dr. Cowper Reed (1908, p. 522), that "There is no evidence of the body being completely surrounded by plates, and the nature of the ventral side is unknown, but it may have been only membranous."

The fact that many of the median plates, in spite of their extremely thin shell and their compression during fossilisation, still retain evidence of being angularly bent along a submedian line extending from the apex, together with the general agreement in structure of all the plates and their relation to each other, leaves no doubt that the plates formed a blade-shaped shell as in *Turrilepas*. It is the angularly bent median plates that would suffer most from compression, and it is the case that in all specimens of *Plumulites* approaching completeness, the median plates are crushed and broken, while the outer plates, even though they are more slender, are well preserved. The thinness of the shell and the consequently shallower muscle-pit or scar, and the greater proportionate length of the kite-shaped plates as opposed to the size of the median plates, are more than probably the causes why in *Plumulites* the plates are found spread out on the death of the animal. After all, one of the specimens of *Turrilepas* has its four columns of plates spread out, and in another the shell is opened to some extent, and there can be no doubt that in *Turrilepas* the soft parts must have been enclosed by plates forming a blade-shaped shell.

These considerations justify and explain the following account of the structure of *Plumulites*.

There are four columns of plates, comprising two median columns of keeled plates, and on each side an outer column of kite-shaped plates, the four columns arranged to form an elongate blade-shaped shell, which permits of no additional columns. The number of plates in a column is at least twenty.

Each plate is distinctly asymmetrical, but the kite-shaped plates correspond in shape and size with those of the opposing series, as apparently do the keeled plates. The keeled plates are heart-shaped, about half the length of the kite-shaped plates. The kite-shaped plates have a strong submedian, longitudinal fold, with a similar but narrower fold near to the distal margin; the submedian and distal folds show as a concavity on the outer surface, and as a convexity on the inner surface.

The apices of the keeled plates forming the two median columns lie next the broad back, and along the back the admedian portions of the plates of one column alternate and intersect with those of the opposing column. Each plate overlaps the plate in front for at least one-third of its length. At the sides the keeled plates are intersected by the kite-shaped plates which meet in loose apposition, their outer margins forming the free margin along which the shell opened. The kite-shaped plates

tend to alternate with those of the opposing series, and their apices do not project freely, but because of the alternation serve to form a continuous margin.

The shell tapers gradually towards each extremity, and in consequence there is a gradual reduction in size of the plates. Except for this reduction there is no modification of the plates at the distal end. Of the proximal extremity nothing certain is known, but there is strong evidence that, as in *Turrilepas*, there was some modification of the plates. Certain plates, termed "cancellated" plates, have been found in association with plates of *Plumulites*, but not actually in position in the shell. Barrande has stated (1872, p. 569) that in a counterpart of the holotype of *P. bohemicus* such a plate is to be observed at the base (see Pl. VIII, fig. 1, and p. 50). These plates are obviously of the same series as the kite-shaped plates, some are from the right side and others from the left, and they agree with the kite-shaped plates in having a submedian longitudinal fold; they differ in the umbo being removed from the apex and in the growth-lines being concentric round the umbo. The cancellated plates cannot belong to the upper part of the shell, and they are almost certainly the modified proximal plates.

Shell exceptionally thin, calcareous, with at least twenty plates in a column, and attaining a length of probably 100 mm.

Nothing is known of the inner structure of the shell and its relations to the soft parts. There is, however, so much in common with the general structure of *Turrilepas* and of *Lepidocoleus*, that there can be little doubt that, were the shell not so thin and the ornament not so much impressed through the shell, it would be possible to discern the muscle-scar in each of the plates of the median keeled columns. One median plate (Pl. VII, fig. 4) does seem to show a muscle-scar, but the evidence is not very conclusive.

Another median plate (see *P. canadensis*, p. 61) shows on its inner surface a minute irregular reticular ornament.

There seems little doubt that *Plumulites* had a blade-shaped shell with four columns of alternating plates, the shell opening along the free margin formed by the meeting of the kite-shaped plates, and that the soft parts were attached to each of the plates composing the two keeled series.

The species of *Plumulites* will now be discussed: first those of which a united shell is available, and afterwards those based on isolated plates. Each of these sets is dealt with in ascending geological order.

*Species represented by a united shell*

## *PLUMULITES BOHEMICUS* Barrande

(Plate VIII, fig. 1)

1868. *Plumulites bohemicus* Barrande: Bigsby, Thes. Silur., p. 197 (name only).
1872. *Plumulites bohemicus* Barrande, Syst. Sil. Bohême, I, Suppl., p. 569, pl. xx, figs. 1, 1 a, 1 b, pl. xxxv, figs. 15–20.

Diagnosis. Kite-shaped plates with the apical part moderately attenuated, the growth-lines comparatively wide-spaced, sigmoidally curved, following the outline of the proximal margin but regularly curved upwards near the outer margin. Median plates with the admedian lobe little produced at its inner proximal angle, and the growth-lines on this lobe only moderately curved upwards.

Distribution. Lower Ordovician (d 1): Wosek, and Sta. Benigna, Bohemia.

Material. The greater part of a shell in the Bohemian Museum (Barrande, pl. xx, fig. 1) from Wosek, here figured (Pl. VIII, fig. 1) from a squeeze taken by Dr. Bather from its counterpart (In.24170), is hereby selected as Lectoholotype. Barrande included in this species three isolated plates of the type called by him "valve fénestrée" (= cancellated plate); the two originals of his pl. xxxv, figs. 15, 16 and 17, 18 are from Sta. Benigna, the other (figs. 19, 20) is from Wosek.

Description. From what has been written by some authors it is obvious that the holotype has been misunderstood. It is embedded in a nodule, and, according to Barrande, has a length of 80 mm., and when complete probably 100 mm., although this estimate of the length seems to be a low one. Its breadth is 36 mm. Probably the greater part of a very large individual is represented by this specimen.

The photograph (Pl. VIII, fig. 1), of a squeeze taken from the natural mould on the counterpart of the holotype, shows that all the plates are spread out, and, although the median plates especially are crushed and broken, it is not difficult to see that there are four columns of plates, namely, two median columns of heart-shaped plates, and two outer columns of kite-shaped plates. Barrande carefully figured an example of each of the two kinds of plates. One median plate near the middle of the specimen shows much of its original convexity, especially on its admedian half. This specimen is of importance, since it exhibits the outside of the shell, for it can be seen that the plates overlap each other from behind forwards. It also shows quite clearly, and particularly so if one compares it with the specimens of *P. peachi* (Pl. VII, figs. 1, 2) which exhibit their inner surface, that the submedian longitudinal fold and the sharper fold between

it and the distal margin are seen as a groove on the outside of the plate, and as a ridge on the inside of the plate.

The distal and proximal extremities of this individual are apparently incomplete, but Barrande has stated that in the counterpart (Pl. VIII, fig. 1) one of the cancellated plates can be seen at the base. Certainly a plate near the base of the specimen and on the right hand has much the appearance of a broken cancellated plate, but the evidence cannot be said to be conclusive. And in any case its relation to the surrounding plates is not clear.

Altogether this specimen, taken in conjunction with the specimens of *P. peachi*, throws much light on the structure of the complete shell in *Plumulites*.

## *PLUMULITES FOLLICULUM* Barrande

(Plate VIII, fig. 2)

1868. *Plumulites folliculum* Barrande, Bigsby, Thes. Silur., p. 197 (name only).

1872. *Plumulites folliculum* Barrande, Syst. Sil. Bohême, I, Suppl., p. 573, pl. xx, figs. 10, 13–17.

DIAGNOSIS. Complete specimens do not show details of plates, so that no satisfactory diagnosis can be given.

DISTRIBUTION. Lower Ordovician (d 2): Mt. Drabow and Trubsko, Bohemia.

MATERIAL. Barrande founded this species on four more or less complete shells (his figs. 13–17) from Trubsko, and a single kite-shaped plate (his fig. 10) from Mt. Drabow, but there seems to be no direct evidence for the reference of the single plate to the same species. In the British Museum are squeezes taken by Dr. Bather from the originals of Barrande's fig. 14 (In.24173) and figs. 15, 16 (In.24172). The original of the last mentioned is hereby fixed as Lectoholotype.

REMARKS. Barrande could not discern in the shells the ornament so characteristic of *Plumulites*, and from the figures it is impossible to make out the contour of the plates, or the number of columns, which J. M. Clarke (1896, p. 138) thought comprised two only. On the published evidence it did not seem probable that these shells belonged to *Plumulites*, but the squeeze of the lectoholotype now available seems to show that there must be four columns of plates, and there are fairly clear indications on certain of the kite-shaped plates of a median longitudinal fold (see Pl. VIII, fig. 2). This specimen is an imprint of the outer surface. There is now no doubt in my mind that Barrande's specimens represent a species of *Plumulites*, but they do not help materially in the elucidation of the structure of the shell because of their bad preservation. The four columns of alternating plates are spread out, and there is a somewhat strongly marked median carination observable for the whole length of the shell.

The kite-shaped plate from Drabow is short and broad, the

proximal margin almost straight, and the proximal angles broadly and almost equally rounded, giving the plate a peculiarly rounded appearance.

## *PLUMULITES PEACHI* (Nicholson & Etheridge, jun.)

(Plate VII, figs. 1–4)

1880. *Turrilepas peachi* Nicholson & Etheridge, Silur. Foss. Girvan, p. 301, pl. xx, figs. 8–10.
1908. *Turrilepas peachi* Nicholson & Etheridge: Reed, *Trans. Roy. Soc. Edinb.*, XLVI, pt. iii, p. 519, plate, figs. 1–5 (non fig. 15).
1914. *Plumulites peachi* (Nicholson & Etheridge): Moberg, *Kgl. Fysiogr. Sällsk. Handl.*, N.F., XXVI, No. 1, pl. i, figs. 7–9.
1915. *Plumulites peachi* (Nicholson & Etheridge): Withers, *Geol. Mag.* (dec. vi), II, p. 114 (fig. 6), p. 122.

Diagnosis. Kite-shaped plates with the apical part moderately attenuated, the growth-lines comparatively wide-spaced, extending almost straight across the plate, but sharply upturned near the outer margin. Median plates with the admedian lobe produced at its inner proximal angle, and the growth-lines on this lobe strongly curved upwards, and with the fold on each side of the median fold narrow and weak.

Distribution. Upper Ordovician. Ashgillian: Drummuck group (Mudstones and Starfish Bed), Thraive Glen, Girvan, Ayrshire. Caradocian: Whitehouse group, Whitehouse Bay, Girvan, Ayrshire.

Material. All the thirty-two specimens studied, of which eleven have counterparts, are in the British Museum, and all from the collection of Mrs. Robert Gray, except I.16527, collected by W. McPherson, 1914.

The syntypes (In.23650, In.23651, In.20964) of Nicholson & Etheridge (1880, figs. 8, 9, 10, respectively) are three incomplete shells, with plates in position, from Whitehouse Bay. In.23650 was refigured by Reed (1908, fig. 4), who referred to it as the "type specimen"; it is therefore fixed here as the Lectohologtype (Pl. VII, fig. 1).

Other specimens from Whitehouse Bay are In.23652–In.23657, In.23659–In.23668, In.23670; In.23671, a median plate (Reed, 1908, fig. 5); and In.23672, an almost complete shell (Pl. VII, fig. 2). This makes twenty-two specimens from the Whitehouse group.

From the Starfish Bed of Thraive Glen there are eight specimens: In.23640, the distal half of a shell, with plates in position (Reed, 1908, fig. 1); In.23641–In.23644, In.23646, In.23647; and In.16527 (McPherson colld.).

From the Mudstones of Thraive Glen are two specimens: In.23648, a single median plate (Reed, 1908, fig. 2); In.23649, two single kite-shaped plates (Reed, 1908, figs. 3, 3 a, erroneously assigned to the Starfish Bed in the explanation of the plate).

From this material, which includes several specimens with

the plates in position, the following are chosen for more detailed discussion here :—the lectoholotype, In.23650 (Pl. VII, fig. 1); a more complete specimen with counterpart, In.23672 (Pl. VII, fig. 2); the original of Reed, 1908, fig. 1, In.23640 (Pl. VII, fig. 3); the original of Reed, 1908, fig. 2, In.23648 (Pl. VII, fig. 4); and two larger shells, In.23642, In.23643. Of these the lectotype and In.23672 are of much morphological importance, for it is possible to get from them a clear conception of the structure of the shell. In.23640 (Reed, 1908, fig. 1), though rather unsatisfactorily preserved, shows the outer surface of the shell.

The "supposed terminal plate" of Reed (1908, fig. 15; In.23669), from the Whitehouse group of Whitehouse Bay, is not very like the figure; but, since the surface has not the prominent growth-lines seen in the median and kite-shaped plates of *P. peachi*, and the structure of the stereom differs from that of the plates occurring in the same bed, it is most unlikely that this plate belongs to the same class of animal, let alone to the present species. It is not unlike some forms of *Pterotheca*.

Description. No good figure has hitherto been given of the lectotype, for while the figure given by Nicholson & Etheridge did not show the median plates satisfactorily, that given by Reed (1908, fig. 4) was restored and inaccurate. The specimen (Pl. VII, fig. 1) shows the inner surface; there can be no doubt of this, for the plates do not overlap each other from behind forwards as they should do if it were the outer surface, and as they do in the related forms *Turrilepas* and *Lepidocoleus*. Owing to the extreme thinness of the shell the ornament has been impressed through the plates.

The specimen consists of five kite-shaped plates and five median plates on the left hand (right side in outer view of shell), and on the opposing side three median plates; where the shell is broken away can be seen the impression of the longitudinal fold of two left kite-shaped plates. All the plates are spread out, and apparently constitute the middle part of a shell. Alternation of the median plates with the kite-shaped plates is quite clearly shown, and the median plates themselves alternate with and overlap each other, for the plates on one side are slightly in advance of those on the other.

The median plates are not clearly seen owing to this overlap and intersection but on the admedian side they still retain some of their original concavity. Isolated examples are seen to be obliquely subtriangular or heart-shaped (Pl. VII, fig. 4). The proximal margin is broadly rounded, somewhat excavated in the middle, the distal and admedian margins strongly convex. A wide longitudinal submedian fold extends from the apex, and in an inner view such as this, the admedian side of the plate is concave; originally the plate must have been angularly bent along this fold. Two further but more delicate folds, hardly

discernible in some plates, extend from the apex, one on either side of the main fold. The fold on the admedian side appears to mark the extent of overlap of the admedian margin of the opposing plate to form the "fixed" margin, and that on the distal side marks the position occupied by the outer proximal margin of the kite-shaped plates. The surface of each plate is marked by regular, transverse, equal and wide-spaced growth-lines, following the outline of the proximal margin, and steeply inclined upwards and closer together on the distal and admedian margins. Owing to the extreme thinness of the shell and the impress through it of the growth-lines, no very satisfactory evidence of a muscle-scar such as is present in the median plates of *Turrilepas* and all the plates of *Lepidocoleus* can be seen, although the single plate In.23648 (Pl. VII, fig. 4) appears to show such a scar.

The median plates forming the two columns slightly alternate with each other and intersect and overlap each other along their admedian margins. On their distal half they intersect with the kite-shaped plates, and the proximal margin of the kite-shaped plates abuts against the narrow longitudinal fold shown so well in the lectotype on the distal half of the median plates. It is important to note that this proves that the median plates alternate with the kite-shaped plates, and only a small portion of the admedian part of each median plate could have been seen in an outer view. The median plates could not possibly have merely overlain the outer surface of the kite-shaped plates as depicted by Reed (1908, figs. 1 and 4).

The kite-shaped plates.—The lectotype shows also that the base of each kite-shaped plate, from the main longitudinal fold distalwards, abuts close up against the main fold of the median plates, and is not at some distance from it as in Reed's fig. 4. Moreover, the longer axes of the kite-shaped plates do not lie at an angle of 75° to the axial line, but are directed towards the distal extremity at a much sharper angle, a feature still better seen in In.23672 (*infra*). The normal position of the outer margin of the kite-shaped plates appears to be close up against the longitudinal fold of the plate next below, and this is well seen in the present specimen, for only the second plate from the distal end is slightly removed from this position. In an outer view the distal margin of each kite-shaped plate would overlap as far as the longitudinal fold of the plate next in front. Besides the main or submedian longitudinal fold, and the narrow longitudinal fold on the distal half of the plate, there are two wide but very shallow longitudinal folds. One of these is seen at the outer margin, and the other occupies the tract between the main longitudinal fold and the narrow fold. These broad folds are represented on the inner surface by a concavity, on the outer surface by a convexity; and on the fold at the outer margin the growth-lines are sharply upturned. In an inner view of the

specimen, such as this, the proximal fold is seen to fit into the shallow fold between the main longitudinal fold and the narrow fold of the plate next below. These folds therefore seem to serve the definite purpose of keeping the plates in their respective positions.

The apical ends of the kite-shaped plates do not appear to have been free but to have formed almost a continuous margin, and although there may have been a slight interval between the apices of the plates, the alternation of the opposing plates would, when the shell was closed, serve to form a continuous margin. The evidence of the lectotype and the specimen next described does not seem to warrant so long an interval, if any, between the apical ends of the plates, as given in Reed's figures. The surface of the kite-shaped plates is marked like that of the median plates, with regular, transverse, equally spaced growth-lines, sharply upturned near and parallel to the proximal margin, and meeting the distal margin almost at right angles.

Specimen In.23672 (Pl. VII, fig. 2) also shows the inner surface of the shell, with the plates spread out. It is the most complete representative of the genus yet known, and apparently lacks only a small part of the proximal extremity. One can see at a glance the general blade-like form of the shell, the structure of the distal end, the alternation of the two series of kite-shaped plates, and one can gain some idea of the length of the shell, and of the number of plates in a column. Owing to the fact that the sides of the shell have been crushed towards the median line, only two or three of the median plates on the right side (left hand) can be clearly seen, for the remaining plates are either crushed or hidden by the bases of the kite-shaped plates. The relation of the median plates to each other, and to the kite-shaped plates, is therefore not nearly so evident as in the lectotype. There are at least seventeen kite-shaped plates shown in the left column, but since the more proximal plates are telescoped into one another, it may be that there are more. The length of shell preserved measures 43·4 mm., and its greatest breadth is 17·3 mm.

Except in size, and their increased outward curvature, the kite-shaped plates at the distal extremity do not show any modification in structure. On the left side the most distal plate has a length of 4·1 mm., the plates gradually increasing in size downwards, the more proximal plate having a length of 10·6 mm. A corresponding change in size is to be seen in the median plates.

There was a possible decrease in size of the plates towards the proximal extremity, but this part of the specimen is incomplete. This specimen, therefore, throws no light on the precise position occupied by the cancellated plates.

All the kite-shaped plates are directed sharply towards the distal extremity, even those near the proximal end, and the outer margin of each plate is seen to abut close up against the longitudinal fold of the plate below, just as in the lectotype.

That the kite-shaped plates alternate with those of the opposing series is clearly shown, especially towards the distal half of the specimen.

Specimen In.23640 (Pl. VII, fig. 3), figured by Reed (1908, p. 521, fig. 1), represents about the distal half of a shell with the plates spread out. It is interesting mainly because, unlike other examples of *P. peachi* with the plates in position, its outer surface is exposed, as inferred from the fact that the plates are seen to overlap from behind distalwards. Although ill-preserved, the kite-shaped plates are in position, about nine or ten on one side, but the median plates are so badly preserved that it is extremely difficult to make out their structure or relations. In any case it does not seem to me that the whole of each median plate occupies a position on the outer side of the kite-shaped plates as in Reed's figure, for this is contrary to what is known in the other specimens, especially the holotype (Pl. VII, fig. 1), where their precise relation can be seen. This specimen is 13 mm. long, and its breadth with the plates outspread 7·2 mm. It is therefore less than half the breadth of In.23672 (Pl. VII, fig. 2), and less than a quarter the breadth of In.23642 from the same bed. While this specimen may be a young example of *P. peachi*, it certainly does not show sufficient characters to enable one to say more than that it is a species of *Plumulites*. In size, structure, and mode of preservation it closely resembles the fossils described by Barrande as *P. folliculum* (see p. 50, Pl. VIII, fig. 2).

The shell has a fairly strong median carination for its whole length, and shows well the rounded outline of the distal end of the shell, where the plates are not at all displaced and retain their general position better than in any other specimen. Unfortunately the fracture of the edges of the kite-shaped plates prevents one from satisfactorily seeing the alternation of the two series. They are, however, inclined distalwards at a sharp angle, becoming more acute towards the distal end of the shell, but the more proximal plates are not nearly at right angles to the median line as figured by Reed, nor do I see any warrant for the comparatively broad interval between their apical ends.

The two remaining specimens from the Starfish Bed (In.23642, In.23643) are in the form of impressions of the inner surface. They have the plates outspread, and resemble the lectotype (Pl. VII, fig. 1), not only because they have about the same number of plates preserved, but they come from about the middle of the shell. Both agree well with the lectotype, although they are about one-third greater in size, for the outspread plates in specimen In.23642 would, if complete, measure quite 40 mm. A single kite-shaped plate on this specimen has a length of about 16 mm.; and on In.23643 a single median plate has a length of about 10 mm., the kite-shaped plates being quite as large as in the former specimen.

## *PLUMULITES* cf. *P. PEACHI*

Here are placed twenty-three specimens not well enough preserved for specific determination. Some of them were referred to *Turrilepas* by Dr. Cowper Reed (1908, pp. 523, 525).

Distribution. Lower Silurian, Lower Valentian: Saugh Hill group of Girvan, Ayrshire. Upper Ordovician, Ashgillian: Redhill Beds and Shoalshook Limestone of Haverfordwest; Staurocephalus Limestone of Windermere. Caradocian: Dufton Shales of Cumberland.

Material. British Museum: four specimens with kite-shaped plates and ill-preserved median plates, from Saugh Hill group, Newlands, Girvan, In.23731–In.23734 (Mrs. Robt. Gray Coll.).

Sedgwick Museum, Cambridge: eighteen specimens, some in counterpart as indicated by the hyphenated numbers (V. M. Turnbull Coll.).

Shoalshook Limestone, Shoalshook Ry. cutting: four kite-shaped plates, Tablet 77, 2894–5, Tablet 78, 3236–7, Tablet 79, 2748–9, Tablet 81, 2960–1; one median plate, Tablet 80, 3050–1.

Redhill Beds, Prendergast Place: three kite-shaped plates, Tablet 72, 1219, Tablet 74, 2999–3000, Tablet 82, 2786–7; a probable median plate, Tablet 83, 1936.

Dufton Shales, Alston Road, Melmerby, Cumberland: eight kite-shaped plates, Tablet 84, 2467–8, Tablet 85, 2471–2, 2473, 2475–6, 2477–8, Tablet 87, 2457–8, Tablet 88, 2093–4, Tablet 98, 3362–3; one median plate, Tablet 85, 2470.

One specimen with associated plates from the Staurocephalus Beds of Backside Beck, Windermere (J. Middlebrook Coll.).

Remarks. Although undoubtedly belonging to *Plumulites* and interesting because of their geological distribution, these plates are either too incomplete or too ill preserved to be referred with confidence to any species. The Ashgillian specimens are very like *P. peachi*, and may indeed be that species, but better material is necessary to prove this. The best preserved kite-shaped plate from the Shoalshook Limestone (Tablet 77, 2894–5) has a length of quite 11 mm.; this is a comparatively large size for the genus, and approaches that of the large specimens of *P. peachi*, of which the largest plate measures about 16 mm. The plates from the Dufton Shales are not so complete or so well preserved, and, as well as the plates from Newlands, Girvan, are too unsatisfactorily preserved for discussion of them to be profitable.

*Species known only from detached plates*

### *PLUMULITES MOBERGI* T. H. Clark

?1888. (?) *Turrilepas* sp.: R. W. Ells, *Geol. Surv. Canada, Ann. Rep.*, III (1887–88), pt. ii, pp. 59 K, 119 K.
1924. *Plumulites mobergi*: T. H. Clark, *Bull. Amer. Paleont.*, X, No. 41, p. 97, pl. ix, figs. 14, 15?.

Diagnosis. Kite-shaped plates with the apical part moderately attenuated, the proximal margin sharply excavated in the middle and convex at the sides, the proximal angles almost equally rounded, and the longitudinal fold situated nearer to the outer margin. Median plates with the outer and inner margins remarkably straight and forming with each other a right angle.

Distribution. Lower Ordovician; Lévis Shales, *Shumardia* zone: Lévis and S.W. end of Island of Orleans, Quebec.

Material. Two isolated plates in the Museum of Comparative Zoology, Cambridge, Mass. One, a kite-shaped plate, is Clark's Holotype (his fig. 14). The other (his fig. 15) was regarded by him as probably a median plate, and there is no reason to doubt that it is one.

Remarks. Clark (1924) appears to agree with Moberg (1914) that *Plumulites* and *Turrilepas* represent distinct genera, but says that this conclusion was reached by G. F. Matthew (1896). Matthew (June, 1896, p. 145), however, only said that it is altogether probable that they are distinct genera, and even this expression of opinion was somewhat nullified by the fact that in his later paper (August, 1896, p. 199) he includes under *Plumulites* " similar plates from the Silurian of England " which actually were *Turrilepas*.

The holotype has a length of about 4·2 mm.; the growth-lines at its proximal end are ·2 mm. apart. The width of the plate proximally is 2·5 mm.

### *PLUMULITES LLANVIRNENSIS* n. sp.

(Plate VIII, figs. 3, 4)

Diagnosis. Like *P. peachi*, but with the kite-shaped plates more attenuated and the growth-lines wider apart. Median plates comparatively longer in proportion to breadth.

Distribution. Lower Ordovician, Skiddavian, Lower Llanvirn series, *Didymograptus bifidus* zone: Long Plantation Cutting, near Scolton, Pembrokeshire.

Material. Two kite-shaped plates (Tablet 16, 3608–9, 3717–18), and three median plates (Tablet 16, 3610, 3611, Tablet 17, 3847–8), in the Sedgwick Museum, Cambridge (V. M. Turnbull Coll.). Of these, No. 3608–9 (Pl. VIII, fig. 4) is taken as Holotype.

Description. All the specimens are merely impressions. Both kite-shaped plates are somewhat distorted by cleavage, and of these the holotype has a length of 8·7 mm., and a breadth of 5·1 mm. The apical part is not clearly shown, but the whole plate is much attenuated, and the growth-lines are comparatively wide-spaced. All three median plates are imperfect so far as their breadth is concerned, but two, 3610, 3847–8, have a length of 10·3 mm., and 10·7 mm., respectively. Although the plates are much flattened, the admedian portion of the median plate (Pl. VIII, fig. 3) still retains some of its original convexity. The growth-lines are more close-set in the median plates than in the kite-shaped plates.

Comparison with other species. These plates are important, for, since they come from the Lower Ordovician (Llanvirnian), they constitute some of the earliest representatives of the genus, of the family, and of the group. So far as the median plates are preserved they resemble those of *P. peachi* from the Upper Ordovician (Starfish Bed) of Girvan, and in fact are quite as large as the largest example from that horizon although they are proportionally longer. The kite-shaped plates do not resemble that species so much, especially in being more attenuated, and in the wide-spaced growth-lines. In the attenuated form of the plate they approach *P. scoticus* from the Upper Ordovician (Balclatchie group) of Girvan, but this form, while an earlier form than *P. peachi*, has much more close-set growth-lines than in *P. peachi*. In the circumstances it seems advisable to give specific rank to this form, especially in view of its low occurrence in the sequence.

## *PLUMULITES COMPAR* Barrande

1872. *Plumulites compar* Barrande, Syst. Sil. Bohême, I, Suppl., p. 570, pl. xx, figs. 2, 4–5.

Diagnosis. Kite-shaped plates moderately short and broad (breadth a little more than one-half the length), with the outer proximal angle widely and regularly rounded, and the inner proximal angle narrowly rounded.

Distribution. Lower Ordovician (d 1) : Wosek, and environs of Sta. Benigna, Bohemia.

Material. The two syntypes in the Bohemian Museum are : a kite-shaped plate from Wosek (Barrande's fig. 2); and a specimen (fig. 4) with its counterpart (fig. 5) from Sta. Benigna, exhibiting a number of associated plates, including the following : a kite-shaped and a median plate (fig. 4 a), a kite-shaped plate (fig. 4 b), a cancellated plate (fig. 5 a), and a median plate (fig. 5 b). This latter specimen is hereby fixed as Lectoholotype.

In the British Museum are three kite-shaped plates from Sta.

Benigna, viz. In.24186, purchased from W. Frič, and In.24184–5, transferred in 1880 from the Museum of Practical Geology.

## *PLUMULITES CONTRARIUS* Barrande

1872. *Plumulites contrarius* Barrande, Syst. Sil. Bohême, I, Suppl., p. 571, pl. xx, figs. 3 a, b.

DISTRIBUTION. Lower Ordovician (d 1) : Wosek, Bohemia.

HOLOTYPE, in the Bohemian Museum, a single specimen probably representing a median plate, although it is somewhat doubtful.

REMARKS. If this plate does represent a median plate of *Plumulites*, then it is distinguished from other species in that the growth-lines or ridges on the outer lobe are inclined sharply downwards from the median fold, instead of curving upwards from the fold to the outer margin.

## *PLUMULITES REGIUS* Barrande

1872. *Plumulites regius* Barrande, Syst. Sil. Bohême, I, Suppl., p. 575, pl. xx, figs. 6, 7, pl. xxxv, figs. 11–14.

DIAGNOSIS. Kite-shaped plates comparatively narrow, breadth half the length, with the proximal margin slightly convex, the inner proximal angle narrowly rounded, and the outer proximal angle obliquely truncated.

DISTRIBUTION. Lower Ordovician (d 1) : Koenigshof, Bohemia. Middle Ordovician (d 3) : Wraz, Bohemia. Upper Ordovician (d 5) : Koenigshof, Bohemia.

MATERIAL. The syntypes in the Bohemian Museum are some associated kite-shaped plates (Barrande's fig. 6), and cancellated plate (figs. 11, 12) from d 5 of Koenigshof, a kite-shaped plate (fig. 7) from d 1 of Koenigshof, and a cancellated plate (figs. 13, 14) from d 3 of Wraz.

The associated kite-shaped plates (fig. 6) are hereby fixed as Lectoholotype.

In the British Museum are squeezes made by Dr. Bather from the originals of Barrande's figs. 11, 12 (In.24177) and figs. 13, 14 (In.24178).

REMARKS. The narrowness of the kite-shaped plates of this species separates it off from other species except *P. gracillimus* Ringueberg, from the Silurian of North America. It is distinguished from that species not only by its larger size, approaching three times the length, but the proximal margin is less convex, and it follows that because of the truncation of the outer proximal angle, the growth-lines along the outer margin are sharply and abruptly upturned.

## *PLUMULITES TRENTONENSIS* n. sp.

(Plate VIII, fig. 5)

1901. *Lepidocoleus jamesi* (Hall & Whitfield): Ruedemann, *Bull. N.Y. State Mus.*, No. 42, p. 521, pl. ii, fig. 11 (non figs. 10, 12).
1901. *Lepidocoleus jamesi* (Hall & Whitfield): Ruedemann, *Bull. N.Y. State Mus.*, No. 49, p. 88.

Diagnosis. Kite-shaped plates short and broad, the apical part not attenuated, and with the proximal angles widely and almost equally truncated.

Distribution. Middle Ordovician, Middle Trenton Beds: Port Schuyler, Albany Co., N.Y.

Holotype. The single kite-shaped plate in the New York State Museum, figured Ruedemann, 1901, pl. ii, fig. 11 (here reproduced Pl. VIII, fig. 5).

Description. This plate is a typical kite-shaped plate of *Plumulites*. It is comparatively short and broad, the breadth being three-quarters the length, the apical half is not attenuated, the longitudinal fold comparatively wide and straight, and the proximal angles widely and almost equally truncated. Growth-lines comparatively wide-spaced, sharply upturned near the distal and outer margins, corresponding to the width of the truncated proximal angles.

Comparison with other species. This plate appears to resemble most closely the species *Plumulites fraternus* Barrande, from the Ordovician (d 3) of Trubin, Bohemia, but more especially the plate figured (1872, pl. xx, fig. 9). *P. fraternus*, however, has the inner proximal angle more rounded, and the outer proximal angle also more rounded but proportionally much wider.

## *PLUMULITES CANADENSIS* (H. Woodward)

1889. *Turrilepas canadensis* H. Woodward, *Geol. Mag.* (dec. ii), VI, p. 274, text-fig.
?1901. *Turrilepas ottawaënsis* nom. nud.: H. M. Ami, Appendix to Report G of the *Ann. Report Geol. Surv. Canada*, n.s., XII (1899), p. 67.

Diagnosis. Median plate with the proximal margin but slightly excavated in the middle, the admedian lobe broadly rounded, and the margin of the outer lobe very slightly convex and forming a sharply rounded angle with the outer part of the proximal margin.

Distribution. Middle Ordovician, Upper Trenton (Collingwood Shale): right bank of Rideau River, Rifle Range, Ottawa; and plates listed from other localities in Ontario.

Holotype. The unique median plate, Brit. Mus., I.4017.

Remarks. This median plate has a length of 5·6 mm., and a breadth of 4·4 mm. For the most part the shell itself is

preserved, and on its inner surface, which is the side exposed, an exceedingly fine reticular structure can be seen. The shell is excessively thin, and bears the impress through it of the growth-lines, but where the shell is broken away can be seen the imprint of the outer surface with the growth-lines more pronounced. This plate is interesting, since it is comparatively deeply concave, and therefore retains much more than is usual of its original shape, for originally the admedian portion of the plate must have been bent almost at right angles to the outer portion along the submedian fold extending from the apex. A further slight longitudinal fold is situated towards the distal margin.

## *PLUMULITES FRATERNUS* Barrande

1872. *Plumulites fraternus* Barrande, Syst. Sil. Bohême, I, Suppl., p. 574, pl. xx, figs. 8, 9, pl. xxxv, figs. 1–6.

Diagnosis. Kite-shaped plates short and broad (breadth three-quarters to two-thirds the length), with the outer proximal angle widely truncated, and the inner proximal angle narrowly rounded.

Distribution. Middle Ordovician (d 3, 4): Trubin and Zahoržan, Bohemia.

Material. The syntypes in the Bohemian Museum are five plates, viz. a kite-shaped plate (Barrande's figs. 1–2) and a cancellated plate (figs. 3–4) from Zahoržan; two kite-shaped plates (figs. 8, 8 a, 9, 9 a) and some associated plates, including a cancellated plate (figs. 5–6), from Trubin. Of these the original of Barrande's fig. 8, from Trubin, is hereby fixed as Lectoholotype.

In the British Museum are two specimens in the Barrande collection from Trubin, one (In.24188) showing a kite-shaped plate, and the other (In. 24817) a median and a kite-shaped plate. Also squeezes made by Dr. Bather from the originals of Barrande's figs. 1, 2 (In. 24174), figs. 3, 4 (In.24175), and fig. 9 (In.24176).

## *PLUMULITES DALECARLICUS* Moberg

1914. *Plumulites dalecarlicus* Moberg, *Kgl. Fysiogr. Sällsk. Handl.*, N.F., XXVI, No. 1, p. 16, pl. ii, figs. 12–17.
1914. *Plumulites dalecarlicus* Moberg: Moberg, *Geol. Fören. Stockholm Förhandl.*, XXXVI, p. 490, figs. 3–5.

Distribution. Middle Ordovician, Black Trinucleus shales: Wikarbyn and Gulleråsen (Sanden) in Ore, Dalecarlia; Röstånga, Scania.

Lectoholotype. The kite-shaped plate represented in Moberg's fig. 12, from Wikarbyn, is hereby selected.

Remarks. Known only from isolated median and kite-shaped plates.

Moberg distinguishes the kite-shaped plates of this species

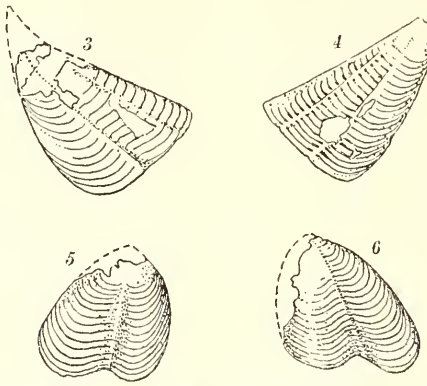
from those of *P. peachi* and *P. scoticus* by the marked sigmoid curve of its growth-lines and the oblique section of the longitudinal groove. Without study of a series of the actual plates I do not feel in a position to discriminate the species.

## *PLUMULITES ESTHONICUS* Withers

(Text-figs. 3–6)

1921, July. *Plumulites esthonicus* Withers, *Ann. Mag. Nat. Hist.* (9), VIII, p. 125, text-figs. 1–4.

Diagnosis. Kite-shaped plates with the apical part moderately attenuated, the growth-lines closely disposed (six to seven to 1 mm.), the outer proximal angle broadly rounded, and the main longitudinal fold nearer to the outer margin. Median




Figs. 3–6.—*Plumulites esthonicus* Withers. × 6 diam. Kite-shaped plates, Fig. 3 (holotype), Fig. 4 (paratype). Median plates, Figs. 5 and 6 (paratypes). Middle Ordovician, Kuckers Stage ($C^2$ of Schmidt): Jaerve, near Kuckers, Esthonia.

plates with the proximal margin deeply excavated in the middle, having a wide and obscure apico-basal fold, the inner lobe being extremely protuberant from the apex.

Distribution. Middle Ordovician, Kuckers Stage ($C^2$ of Schmidt): Jaerve, nr. Kuckers, 10 km. N.W. of Jewe Station, Esthonia.

Material. Thirteen pieces of shale, with several median and kite-shaped plates. Holotype, a kite-shaped plate (1921, fig. 1, and Text-fig. 3 above) in the Geological Museum of the University of Tartu (Dorpat). One of the figured paratypes (1921, fig. 3, our Text-fig. 5) and seven unfigured are in the same collection. The other paratypes—a kite-shaped plate In.20588

(1921, fig. 2, our Text-fig. 4), a median plate In.20589 (1921, fig. 4, our Text-fig. 6), In.20590, and In.20591—are in the British Museum: collected and presented by H. Bekker, 1921.

Description. The plates are all much flattened and imperfect, and are preserved as mere films standing out white on the rusty-brown shale; they are of two kinds, the median heart-shaped plates and the outer kite-shaped plates. No cancellated plate has been noticed.

Median plates roughly heart-shaped, broad, short, subtriangular, with the apex directed inwards, and a rather wide ill-defined fold extending from the apex to the excavated portion of the proximal margin, the largest plate having a height of 3·8 mm. Proximal margin sinuous, the middle portion deeply excavated; inner (fixed) margin rounded and markedly protuberant from the apex, much more so than is the outer (free) margin. The growth-lines are very closely disposed, in some measure no doubt due to crushing, and they are directed upwards on the margins, but to a greater extent on the inner margin.

Outer plates kite-shaped, somewhat curved distally with pointed apex, and a narrow submedian fold extending the whole length of the plate and situated slightly nearer to the outer margin, and there is a similar but narrower fold near and parallel to the inner margin. The proximal margin is slightly sinuous, being slightly excavated in the middle, the outer proximal angle is broadly and regularly rounded, and the inner proximal angle narrowly rounded; inner margin very slightly concave, the proximal half almost straight; outer margin slightly convex. The growth-lines are closely disposed, six to seven to 1 mm., equidistant, crossing the median apico-proximal fold at right angles, slightly concave on the inner half of the plate and a little upturned at the inner margin; on the outer half they are broadly curved upwards, and towards the outer margin are more crowded together.

Comparison with other species. *Plumulites esthonicus* appears to agree most closely with *P. rastritum* Moberg, from the Lower Silurian (Rastrites shales) of Sweden, and *P. peachi* Nicholson & Etheridge, from the Upper Ordovician of Scotland. From *P. rastritum* it differs in the median plates by the more rounded and protuberant admedian lobe, and in the kite-shaped plates by the longitudinal fold being nearer to the outer margin instead of to the distal margin. From *P. peachi* it differs in that the median plates have the admedian lobe more protuberant, the margin being more fully rounded to the apex, while in the kite-shaped plates the growth-lines of the outer lobe are more regularly curved and consequently the outer proximal angle is more regularly rounded; the growth-lines are more closely disposed, and none of the known plates attains to more than one-third the size of the largest-known plates of *P. peachi*.

## *PLUMULITES TÖRNQUISTI* Moberg.

1914. *Plumulites törnquisti* J. C. Moberg, *Kgl. Fysiogr. Sällsk. Handl.*, N.F., XXVI, No. 1, p. 18, pl. ii, figs. 19, 20.

Distribution. Middle Ordovician, Black Trinucleus shales: Wikarbyn, Dalecarlia.

Material. The syntypes are two detached plates. Of these the kite-shaped plate (Moberg's fig. 19) is hereby fixed as Lectoholotype. The original of his fig. 20 was regarded as doubtfully a median plate.

Remarks. The lectoholotype is very like a kite-shaped plate of *P. dalecarlicus* from the same horizon, and since we know that these plates are somewhat variable, it may be that only one species is represented. Moberg points out that it is more acuminate and that the curvature of the growth-lines is more strongly marked, features which may, as he admits, depend on its more distal position in the shell. The original of Moberg's fig. 20 may not be a median plate, but if it is, it is very different from the median plates of *P. dalecarlicus* and of other undoubted species of *Plumulites*.

## *PLUMULITES SCOTICUS* (R. Etheridge, jun.)

(Plate VII, figs. 5–7)

1876. *Plumulites* sp., J. Armstrong, J. Young, & D. Robertson, Cat. West. Scot. Foss., p. 15.
1878. *Turrilepas scotica* R. Etheridge, jun., *Proc. R. Phys. Soc. Edinburgh*, IV, p. 166, pl. ii, figs. 1, 2.
1879. *Turrilepas scotica* Etheridge: Nicholson & Etheridge, Silur. Foss. Girvan, p. 214, pl. xiv, figs. 22–27 (non fig. 25).
1908. *Turrilepas scotica* Etheridge: Reed, *Trans. Roy. Soc. Edinburgh*, XLVI, pt. iii, p. 523, plate, figs. 7–12, 14, 15 (non figs. 6, 13).
1914. *Plumulites scoticus* (Etheridge): Moberg, *Kgl. Fysiogr. Sällsk. Handl.*, N.F., XXVI, No. 1, pl. i, figs. 10, 11.
1914. *Plumulites* cfr. *scoticus* (Etheridge): Moberg, *Geol. Fören. Stockholm Förhandl.*, XXXVI, p. 490, figs. 1–2.

Diagnosis. Kite-shaped plates with the apical part slender and much attenuated, the growth-lines more numerous and close-set than in *P. peachi*. Median plates with the fold on each side of the median fold usually broader and more distinct than in *P. peachi*.

Distribution. Upper Ordovician, Caradocian, Balclatchie group: Ardmillan, Balclatchie, and Dow Hill, Girvan, Ayrshire.

Material. There are in the British Museum fifty-seven specimens (fifteen with counterparts), all from Mrs. Robert Gray's Collection, and comprising all the specimens figured by Etheridge, Nicholson & Etheridge, and Reed, except the original of Nicholson & Etheridge, 1879, pl. xiv, fig. 27, which cannot be traced.

The two syntypes of Etheridge (1878) were kite-shaped plates

from Balclatchie: In.23676 (his fig. 1) and In.23675 (his fig. 2). Of these, In.23676 is hereby fixed as Lectoholotype.

The syntypes were again figured by Nicholson & Etheridge (1879) with four other isolated plates from Balclatchie; the six thus comprise three kite-shaped plates, In.23675 (fig. 22), In.23674 (fig. 23), In.23676 (fig. 24), a median plate, In.23677 (fig. 26), a cancellated plate (fig. 27), and another plate, In.23708 (fig. 25), which evidently belongs to the median series of some other form (see *Deltacoleus*, p. 43). Cowper Reed (1908) refigured this last (fig. 13) with In.23674 (fig. 11), In.23675 (fig. 12) and the following plates from Dow Hill: two kite-shaped, viz. In.23709 (fig. 7), In.23711 (fig. 9), one median, In.23710 (fig. 8), and one cancellated, In.23712 (fig. 10); also a piece of mudstone from Balclatchie, In.23678, bearing a number of kite-shaped plates (fig. 14) and a supposed terminal plate (fig. 14 a).

The remaining specimens are: from Balclatchie, median plates, In.23679, In.23690, In.23703–In.23707, kite-shaped plates, In.23680–In.23689, In.23691–In.23702; from Dow Hill, kite-shaped plates, In.23715–In.23730, cancellated plates In.23713, In.23714; from Ardmillan, a kite-shaped plate, In.23738.

Two kite-shaped plates from Sweden have been figured by Moberg (1914) as *Plumulites* cfr. *scoticus*.

Remarks. The species *P. scoticus* is therefore represented only by disconnected plates. Of these we know that the kite-shaped plates, the median plates, and the cancellated plates, occurring together in the Balclatchie group, could have belonged to the same form, for similar plates appear to be present in the counterpart of a specimen of *P. bohemicus* described and figured by Barrande (1872, p. 569, pl. xx, fig. 1).

The associated kite-shaped plates from Balclatchie figured by Reed (1908, fig. 14, In.23678) as *P. scoticus* are much smaller than is usual for that species, and none is complete enough to show its entire outline. Among them is a plate figured by Reed (fig. 14 a) as a "supposed terminal plate," but the evidence for that interpretation is far from convincing. The figure certainly suggested to me that it might represent the distal end of a cancellated plate, but the specimen fails to show any trace of the concentric lines as drawn in the figure. On the contrary, a certain ill-defined line or ridge can be seen extending right across the plate from the small excavation shown on one side; and this suggests that the plate consists merely of about one-half of the proximal extremity of a kite-shaped plate or even a median plate. However this may be, the shape and ornament of the plate are too indefinite upon which to base such a clear-cut figure as given by Reed.

The small convex triangular plate from Balclatchie (In.23708) figured as *T. scotica* by Nicholson & Etheridge (1879, pl. xiv, fig. 25) and by Reed (1908, fig. 13), as well as the much larger

plate from Dow Hill (In.23673), figured by Reed (1908, fig. 6) as *Turrilepas* sp., and doubtfully referred in his text to "*T. scotica*," are dealt with under the new genus *Deltacoleus* (see p. 43).

The kite-shaped plates, the median plates, and the cancellated plates are therefore the only plates here regarded as belonging to *P. scoticus*, and the species thus appears to be distinguished from *P. peachi* in the slender and more attenuated apical portion of the kite-shaped plates, but particularly in the more numerous and close-set growth-lines on all the plates.

All four cancellated plates of this species examined by me, including that figured by Reed (1908, fig. 10, here re-figured Pl. VII, fig. 7), are curved either towards the right or left, just as are the cancellated plates of other species figured by Barrande, although the curvature is weak in some instances. The longitudinal fold is not straight or placed medially, but is situated a little nearer to the concave or distal margin, towards which it is curved. There can be no doubt that these cancellated plates are of the same series as the kite-shaped plates.

### *PLUMULITES MINIMUS* Barrande

1872. *Plumulites minimus* Barrande, Syst. Sil. Bohême, I, Suppl., p. 575, pl. xx, figs. 11, 18.

Diagnosis. Kite-shaped plates small, short and broad (breadth two-thirds the length), the proximal margin convex but slightly indented in the middle, and the proximal angles moderately to broadly rounded.

Distribution. Lower Silurian (e 1) : Borek, Bohemia.

Material. The syntypes in the Bohemian Museum are two kite-shaped plates (Barrande's figs. 11 a, b; figs. 18 a, b). Of these the kite-shaped plate (figs. 11 a, b) is hereby fixed as Lectoholotype.

Without more complete material it is not possible to draw up a really satisfactory diagnosis.

### *PLUMULITES DELICATUS* Barrande

1872. *Plumulites delicatus* Barrande, Syst. Sil. Bohême, I, Suppl., p. 572, pl. xx, fig. 12, pl. xxxv, figs. 7–10.

Diagnosis. Kite-shaped plates small, short and broad (breadth four-fifths the length), with the proximal margin forming a sigmoidal curve weakly and widely concave in the middle, outer margin convex, distal margin moderately concave, and the inner proximal angle rounded and somewhat protuberant.

Distribution. Lower Silurian (e 2) : Collines de Listice, near Beraun, Bohemia.

Material. The syntypes in the Bohemian Museum are a kite-shaped plate (Barrande's figs. 7, 8, 12), and a cancellated plate

(figs. 9, 10). Of these the kite-shaped plate (figs. 7, 8) is hereby fixed as Lectoholotype.

Without more complete material it is not possible to draw up a more satisfactory diagnosis.

## *PLUMULITES DISCRETUS* Barrande

1872. *Plumulites discretus* Barrande, Syst. Sil. Bohême, I, Suppl., p. 572, pl. xx, fig. 25.

Distribution. Lower Silurian (e 2): Dlauha Hora, near Beraun, Bohemia.

Material. The Holotype in the Bohemian Museum is a single plate which might represent a median plate, but which may prove on examination to be a plate of *Lepidocoleus*. A squeeze of the holotype is in the British Museum, In.24171, but is insufficient for discrimination of the species.

## *PLUMULITES PYGMAEUS* Moberg

1914. *Plumulites pygmaeus* Moberg, *Geol. Fören. Stockholm Förhandl.*, XXXVI, p. 494, figs. 9–12.

Diagnosis. Kite-shaped plates minute (1 mm. by 0·5 mm.), narrow, breadth about half the length, apical part much attenuated, proximal margin sigmoidal with a short submedian emargination, outer proximal angle widely and broadly rounded, inner proximal angle narrowly and sharply rounded.

Distribution. Lower Silurian, upper part of Rastrites shales: Gulleråsen (Sanden) in Ore, Dalecarlia.

Lectoholotype. The kite-shaped plate represented in Moberg's figs. 9, 10 is hereby selected.

Remarks. Known only from detached median and kite-shaped plates, which do not permit a more satisfactory diagnosis.

## *PLUMULITES RASTRITUM* Moberg

1914. *Plumulites rastritum* Moberg, *Geol. Fören. Stockholm Förhandl.*, XXXVI, p. 493, figs. 7, 8.

Distribution. Lower Silurian, Rastrites shales: Kallholn (bäcken) in Orsa, Dalecarlia.

Lectoholotype. The two median plates and one kite-shaped plate in association, shown in Moberg's fig. 7.

Remarks. Besides the lectoholotype, the species is represented by numerous median and kite-shaped plates. Moberg distinguishes the kite-shaped plates from those of the Trinucleus shales (*P. törnquisti* and *P. dalecarlicus*) thus: less oblique: median longitudinal fold less sharp, almost straight except for a slight curve in harmony with the slight distal-ward curvature of the apex; proximal margin almost straight; distal fold well

marked, half-way between median fold and distal margin; growth-lines well marked and strongly curved in the proximal half.

### *PLUMULITES GRACILLIMUS* Ringueberg

1888. *Plumulites gracilissimus* [sic] Ringueberg, *Proc. Acad. Nat. Sci. Philad.*, 1888, p. 136, pl. vii, figs. 8, 8 a.
1889. *Plumulites gracilissimus* Ringueberg: Lesley, Geol. Surv. Pennsylvania, Rep. P 4, II, pp. vii, 723, figs.
1889. *Turrilepas gracillimus* Ringueberg: S. A. Miller, N. Amer. Geol. Pal., p. 569.

Diagnosis. Kite-shaped plates small, comparatively narrow, breadth half the length, with the proximal margin convex, and the proximal angles narrowly and almost equally rounded.

Distribution. Middle Silurian, Clinton Group, Rochester shales: Lockport, New York.

Material. The author states that from the lower third of the shale at Lockport only separate plates have as yet been found. He figured a kite-shaped plate in his own collection, and that must be regarded as the Holotype. It conclusively proves that *Plumulites* (s. str.) occurs in the Silurian rocks of North America.

Description. Kite-shaped plates curved distalwards, comparatively narrow, breadth exactly half the length, small, length 6 mm. Proximal margin convex, and the proximal angles narrowly and almost equally rounded. Outer margin convex, distal margin slightly concave, almost straight. A narrow longitudinal fold extends down the middle of the plate, and there is a further slight fold midway between it and the distal margin. The growth-lines number twelve or more, following the outline of the convex proximal margin.

Remarks. Ringueberg states that this species approaches *P. minimus* Barrande in size, but is more elongate like *P. delicatus* Barrande, from which it differs in having a narrower central elevation. It is certainly more elongate than either of those species.

### *PLUMULITES YERINGIAE* (Chapman)

1910. *Turrilepas yeringiae* Chapman, *Proc. Roy. Soc. Victoria* (n.s.), XXII, p. 106, pl. xxviii, fig. 2; also XXIX, pt. ii, p. 125, March, 1917.
1914. *Turrilepas yeringiae* Chapman: Chapman, Australian Fossils, p. 243, fig. 115 B.

Diagnosis. Kite-shaped plates long and narrow, breadth about half the length, proximal margin apparently feebly convex, inner proximal angle sharply rounded, outer proximal angle flatly rounded, due to the sharp upward turn of the growth-lines near the outer margin.

Distribution. Silurian (Yeringian): loc. B 16, about 1½

miles below Simmons' Bridge Hut on the Yarra (Upper Yarra District), Victoria. Some plates, possibly of this species, were also found in the Yeringian at loc. B 23, junction of Woori Yallock and Yarra (Chapman, March, 1917).

HOLOTYPE. The associated remains of five outer or kite-shaped plates.

REMARKS. The published figure is scarcely enough for satisfactory discrimination of the species.

## *PLUMULITES ORNATUS* (Chapman)

1910. *Turrilepas ornatus* Chapman, *Proc. Roy. Soc. Victoria* (n.s.), XXII, p. 105, pl. xxviii, fig. 1, pl. xxix, fig. 2.
1910, Aug. *Turrilepas ornatus* Chapman: Chapman, *Victorian Natural.*, XXVII, p. 69 (list only).

DIAGNOSIS. Kite-shaped plates moderately attenuated, breadth about two-thirds the length, proximal margin strongly convex, outer proximal angle widely rounded, inner proximal angle angularly rounded, and the surface ornamented with fine, interrupted radial striae.

DISTRIBUTION. Silurian (Melbournian): type-loc. Yan Yean Reservoir tunnel, near Whittlesea, Victoria; paratype from South Yarra, Victoria.

MATERIAL. The Holotype (Chapman's fig. 1) is a single outer or kite-shaped plate, and the paratype (fig. 2), though taken doubtfully as a median plate by Mr. Chapman, seems to be the proximal portion of a similar but relatively larger plate.

## *PLUMULITES MITCHELLI* (R. Etheridge, jun.)

1890. *Turrilepas mitchelli* Etheridge jun., *Geol. Mag.* (dec. iii), VII, p. 337, pl. xi, figs. 1, 2, 4, 5.
1914. *Turrilepas mitchelli* Eth., jun.: Chapman, Australian Fossils, p. 241, fig. 115 A.

DISTRIBUTION. ? Wenlockian, Bowning Beds, Lower Trilobite Bed: Bowning Creek, New South Wales.

MATERIAL. The Holotype (fig. 1 of Etheridge) consists of a number of displaced kite-shaped plates, and with it were several " cancellated plates."

REMARKS. According to the author, the plates " in their disunited condition form a long, slender, sack-like body, one inch and an eighth in length, by an eighth in width." Although the plates certainly do not belong to *Turrilepas*, but agree with those of *Plumulites* in most of their characters, especially in the presence of a longitudinal fold, they present, on any interpretation of Etheridge's figures, some features that arouse suspicion. If his fig. 2 represents a kite-shaped plate, then it differs from those of all other species in being much less attenuated, in its almost oval outline due to the convergence of the sides towards

the proximal margin, and in the regular upward curvature of the growth-lines from each side of the median fold. If, on the other hand, fig. 2 represents a cancellated plate, then it differs remarkably in the acute apex; a feature only a little less pronounced in figs. 4 and 5.

I refrain, therefore, from attempting a diagnosis of this species.

## *PLUMULITES* sp.

1908. *Plumulites wrightii* H. Woodward: P. Stepanov, *Verhandl. russ. miner. Ges.*, (2), XLVI, p. 197, pl. ii, fig. 16.

DISTRIBUTION. Middle Silurian (Wenlockian): Lake Balkhash, Western Siberia.

REMARKS. A single plate is figured by Stepanov, and considered by him to belong to the species *Plumulites wrightii* [= *Turrilepas wrightiana*]. The figure given, however, seems to resemble more closely one of the "cancellated plates" of *Plumulites* (s. str.) than any of the plates belonging to the species *Turrilepas wrightiana.*

## *PLUMULITES* sp.

1879. *Turrilepas haswelli* Salter MS.: Nicholson & Etheridge, Silur. Foss. Girvan, II, p. 215.

1899. *Turrilepas haswelli* (Edgell MS.): *Mem. Geol. Surv.*, Silur. Rocks Britain, I, Scotland, p. 709 (in list).

DISTRIBUTION. Upper Silurian, Upper Ludlow: Deerhope Burn, Pentland Hills.

REMARKS. Nicholson & Etheridge (1879, p. 215) state: "In the Museum of Practical Geology are some 'cancellated plates' from the Deerhope Burn, Pentland Hills, which closely resemble that [*Plumulites scoticus*] from Girvan. To these Mr. Salter applied the MS. name *T. Haswelli*." In the Silurian Rocks of Britain, I, Scotland, p. 709, this MS. name is ascribed to Edgell. I have a note of four specimens, labelled "*T. haswelli* Salter MS.," in the Museum of Practical Geology and registered 28282 (cancellated and kite-shaped plate), and 28283–5 (cancellated plates). It is unfortunate that owing to the temporary closing of that museum these specimens were not available for critical study, but this note is included since the specimens represent the only remains of *Plumulites* certainly from the Upper Silurian.

There is, however, in the Museum of Practical Geology a single median plate of *Plumulites* (marked J. M. 1645) from rocks of supposed Silurian (possibly Ludlow) age, discovered in the Bobbing boring, W. of Sittingbourne Station, Kent. This was determined by me, and recorded in *Mem. Geol. Surv. Gt. Britain*, "The Concealed Mesozoic Rocks in Kent," 1923, p. 159.

## *PLUMULITES DEVONICUS* J. M. Clarke

1882. *Plumulites devonicus* J. M. Clarke, *Amer. Journ. Sci.*, (3), XXIV, p. 55, text-figs. 1, 2.
1888. *Turrilepas devonicus* (J. M. Clarke): Hall & Clarke, Palaeont., New York, VII, p. 216, pl. xxxvi, fig. 3.

DIAGNOSIS. Kite-shaped plate moderately attenuated (breadth two-thirds the length), proximal margin convex and a little produced in the middle, the inner proximal angle slightly protuberant, and the outer proximal angle weakly truncated.

DISTRIBUTION. Middle Devonian, Hamilton group, base of Hamilton Shales: Canandaigua and Hopewell, Ontario Co., New York.

MATERIAL. Based on two plates, a kite-shaped plate, from Canandaigua (1882, fig. 1), and a plate with the umbo slightly removed from the apex, from Hopewell (1882, fig. 2). The latter may be a new form of cancellated plate; otherwise I do not know what it is. The kite-shaped plate only was figured by Hall & Clarke (1888), and undoubtedly belongs to a species of *Plumulites*. It is here selected as the Holotype.

## DOUBTFUL SPECIES OF MACHAERIDIA

Besides the species already mentioned under *Turrilepas* and *Plumulites*, those next mentioned have also been described as belonging to those genera.

E. O. Ulrich (1880, p. 8) listed, without description or figure, the name *Plumulites ? ? dubius*, and some specimens with this name from the Ordovician (Lorraine group) of Covington, Kentucky, were obtained from Dr. Ulrich in 1898 for the British Museum. Though unable to assign these curious fossils to any other group, I am quite certain that they have no possible connection with either *Plumulites* or its allies.

C. D. Walcott (1884, p. 88) described a single plate from the Ordovician (Pogonip group) of the Eureka District, Nevada, as *Plumulites*, but from the short description it would seem more likely that it belongs to *Lepidocoleus*.

Hall & Clarke (1888) described as many as eight species under the genus *Turrilepas*, and except for *T. devonicus* (here referred to *Plumulites* s. str., see above), none of them can with any confidence be referred either to *Turrilepas* or *Plumulites*. They include *Turrilepas* (?) *newberryi* R. P. Whitfield, originally described as *Plumulites* (1882, p. 217), from the Upper Devonian, Chemung group (Cleveland shale); *Turrilepas cancellatus* and *T. flexuosus*, from the Middle Devonian, Upper Helderberg group (Corniferous Limestone); *Turrilepas foliatus*, *T. nitidulus*, *T. squama*, and *T. tener*, from the Middle Devonian, Hamilton group (Hamilton shales). While these do not belong to *Turrilepas* or *Plumulites*, they may yet belong to the same group of animals,

and it is not unlikely that certain of the plates from the Hamilton shales may be shown to belong to *Strobilepis spinigera*, a supposed allied form occurring in the same beds.

Aurivillius (1892, p. 12, fig. 9 of pl.) figured under the name *Pollicipes validus*, a fossil from bed *c* (= Wenlock shale) of Gotland. This he considered to represent the scutum of a Cirripede, but it seems from the figure to be part of the shell of a form of *Lepidocoleus*. This opinion has been expressed by me already (1915, p. 119), but an examination of the fossil would be necessary to confirm it. Prof. Moberg (July 1914, p. 3), since the name *P. validus* was preoccupied by Steenstrup, 1839, re-named this fossil *Pollicipes aurivillii*, but did not offer any suggestion as to its nature; it certainly is not a scutum of a *Pollicipes*.

G. F. Matthew (June, 1896, p. 145, text-fig. 1; Aug., 1896, p. 200, pl. xiv, fig. 7) has described a species, *Plumulites manuelensis*, from the Cambrian (*Paradoxides* beds) of Manuel Brook, Newfoundland. It is on the evidence of this plate, which certainly does not belong to *Turrilepas* or *Plumulites*, and the equally doubtful plates included by Dr. Matthew in his genus *Cirripodites* and in *Stenotheca* Salter, that Cirripedes have been recorded in the text-books as from Cambrian rocks.

Ami (1896) briefly described as "*Turrilepas*, sp. nov. No. 1 and No. 2," from the Lower Ordovician Phillipsburg series of Stanbridge, Quebec, two plates which are probably *Plumulites*.

R. Ruedemann (1901, p. 577, pl. ii, figs. 13–15) figured and described two isolated plates from the Trenton group (Snake Hill beds) of Mechanicsville, Saratoga Co., New York, as *Turrilepas filosus*; but these plates are quite unlike any plates known in *Turrilepas* or *Plumulites*. They may, however, belong to some allied form.

M. Gortani (1911, p. 213, pl. xx, fig. 16) figured a single fossil from the Middle Devonian of Monumenz, Carnic Alps, Italy, as *Turrilepas* sp. It is stated by the author to be the first record of the genus from Italy, but his figure neither convinces one that the fossil is a plate of *Turrilepas* or *Plumulites*, nor enables one to say what it really is.

Two plates from the Upper Ordovician were figured by Prof. Moberg. One, *Turrilepas* ? (1914, July, p. 18, pl. ii, fig. 22), from the Leptaena limestone of Gullerâsen, Dalecarlia, certainly does not look much like a plate of *Turrilepas* or *Plumulites*, but may be the distal terminal plate of a species of *Lepidocoleus*. The remaining plate from the Chasmops limestone of Nässja, Ostergötland, is one on which Prof. Moberg has ventured to base a new species, *Turrilepas oriens* (1914, Nov., p. 493, text-fig. 6). It is bilaterally symmetrical, triangular in outline, and strongly convex transversely. No plate like this is known in *Turrilepas* or *Plumulites*, and, as in the case of other isolated plates figured by other authors, one will have to await further discoveries before it can be assigned to any particular genus.

Finally, A. Wurm (1925, p. 89, pl. iii, fig. 19) has described and figured as "Cirripedierreste?" a fossil from the Middle Cambrian (*Paradoxides*-schichten) of Galgenberg, near Wildenstein, in the Bavarian Frankenwald. This fossil certainly does not represent a plate of either *Lepidocoleus*, *Plumulites*, or *Turrilepas*, and its reference to the Cirripedia is extremely problematic.

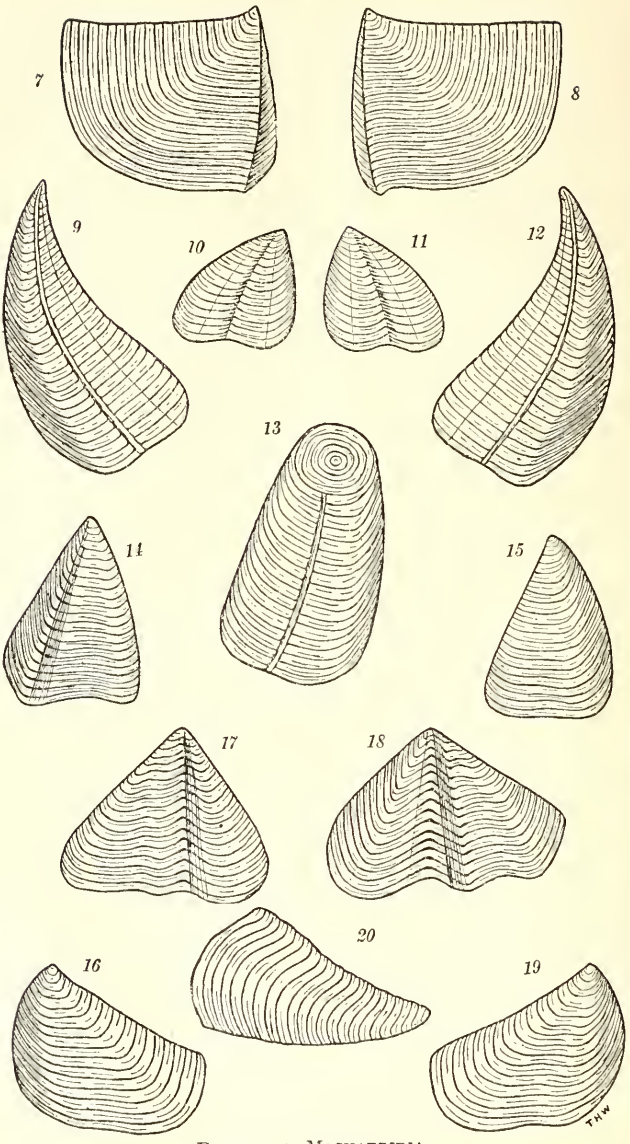
## COMPARISON AND RELATION OF THE GENERA

It has been shown in the foregoing descriptions that the essential structure of *Lepidocoleus*, with its two columns of plates, and of *Turrilepas* and *Plumulites*, each with four columns of plates, is that of an elongate blade-shaped shell.

The relation of the animal to the shell must have been precisely the same in all three forms, for the presence of a muscle-scar in the two opposing series of plates in *Lepidocoleus*, and in the keeled plates in *Turrilepas*, suggests not only that the animal was attached along the whole extent of the shell, but that the shell opened along the narrow free margin where the plates were merely in loose apposition. The thinness of the plates and the impression of the ornament through the shell prevents the muscle-scar being seen in the median plates of *Plumulites*, but the structural relationship of *Plumulites* to *Turrilepas* is undoubted, and in fact by most authors the two forms are considered to represent a single genus. Except that it has only two columns of plates instead of four, *Lepidocoleus* has the same general structure as *Turrilepas* and *Plumulites*.

The separate plates of *Lepidocoleus* are readily distinguished from those of *Turrilepas* and *Plumulites*, since they range roughly from square to oblong in shape, the distal and proximal margins being sub-parallel, as are usually the fixed and free margins, and the admedian portion is variously produced.

Now that it has been possible to make a detailed examination of specimens apart from figures, we see that in *Turrilepas* and *Plumulites* the difference lies essentially in the form of the plates. In both genera the two inner or median columns of plates are keeled and subtriangular, but while in *Turrilepas* these plates are somewhat saddle-shaped, in *Plumulites* they are heart-shaped. The outer columns of plates in both forms are kite-shaped, but those of *Plumulites*, while usually more acuminate, are readily distinguished by the presence of a strong median longitudinal fold, and a weaker longitudinal fold extending near and parallel to the distal margin. The "cancellated" plates of *Plumulites*, which are probably the proximal plates, are quite unlike the proximal plate in *Turrilepas*.

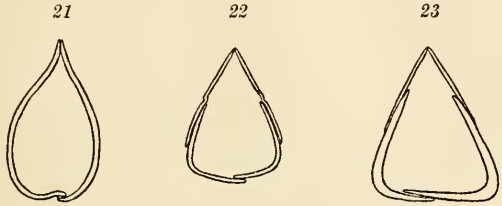



PLATES OF MACHAERIDIA.

The figures on the opposite page bring out the difference in the form of the plates, and will help the proper reference of isolated plates to their appropriate genus.

Figs. 7, 8.—*Lepidocoleus* (left- and right-hand plates).
Figs. 9–13.—*Plumulites*. Figs. 9, 12, outer or kite-shaped plates (left and right); Figs. 10, 11, median or keeled plates (left and right); Fig. 13, supposed terminal or proximal plate (right).
Figs. 14–15.—*Leltacoleus* n. g. Fig. 14, median or keeled plate (right); Fig. 15, outer plate (right).
Figs. 16–20.—*Turrilepas*. Figs. 17, 18, median or keeled plates (left and right); Figs. 16, 19, outer plates (left and right); Fig. 20, terminal or proximal plate.

The plates are variously enlarged, but the relative proportions of the plates in *Lepidocoleus*, *Plumulites*, and *Turrilepas* is correct.




Transverse Sections (Diagramatic) of Shell.

# SYSTEMATIC POSITION OF THE MACHAERIDIA

Although *Lepidocoleus*, *Turrilepas*, and *Plumulites* are now more or less generally accepted as Cirripedes, even in the more recent text-books, there has in the past been considerable uncertainty regarding their zoological position, and in consequence they have from time to time been referred to different groups.

*Turrilepas* was originally described by de Koninck (1857) as a Chiton, a member of the Polyplacophorous Mollusca, but was subsequently considered by H. Woodward (1865), when giving it the name it now bears, to be a Cirripede. In the meantime Reuss (1864) had called attention to some similar fossils from Bohemia named in MS. by Barrande as *Plumulites*, also regarded by those palaeontologists as Cirripedes. These were eventually described by Barrande (1872) under that name, but included with them were some plates of *Lepidocoleus*.

A year later, J. W. Salter (1873), in his posthumous Catalogue, grouped under the Annelida H. Woodward's *Turrilepas wrightiana*, together with another species, *T. ketleyanus*, which really belongs to the genus *Lepidocoleus*.

S. A. Miller (1875), in a note on *Plumulites jamesi*, a species which was made the genotype of *Lepidocoleus*, suggested that it might represent the long-sought appendage of a Trilobite.

H. Woodward (1871, p. 72; 1880, pp. 196, 197, 201), in spite of the fact that he gained almost general acceptance for the Cirripede nature of *Turrilepas*, suggested in a number of footnotes that *T. wrightiana* might possibly prove to be the stem of *Ateleocystites* [i.e. *Placocystites*] *forbesianus* (de Kon.), one of the Anomalocystidae. In the same papers he figured as the stem of that same Cystid, a fossil which we have shown (p. 21) to be part of the shell of *Lepidocoleus ketleyanus*. He later (1889), however, described under *Turrilepas* the species *Plumulites canadensis*, which was definitely referred to the Cirripedia. No mention was made as to the possibility of its being part of a Cystid stem, although he again pointed out (1889, p. 274) that the same ornament occurred on the Cystid *Ateleocystites*.

C. W. S. Aurivillius (1892, p. 23) said of *Turrilepas*: "Die Lepadidennatur dieser Gattung nicht bewährt."

Dr. F. R. C. Reed (1901, p. 109) doubted whether his *Turrilepas ?? ketleyanus* (ex Salter MS.), here referred to *Lepidocoleus*, was

the remains of a Crustacean, and stated : " it has been suggested [by Dr. H. Woodward] with much probability that it represents the column of one of the Anomalocystidae." He later (1908), however, described an almost complete shell of *Lepidocoleus* [= *L. grayae* Withers, 1922] as an Annelid allied to *Cornulites* and *Conchicolites*, and (1908) described under *Turrilepas*, specimens referable to *Plumulites* and *Lepidocoleus*.

We see, therefore, that in addition to the fact that there has been some considerable confusion as regards their generic reference, these Palaeozoic fossils have been referred to the Mollusca (Polyplacophora), Echinoderma (Cystidea), Annelida, and Arthropoda (Trilobita and Cirripedia).

Whatever their true zoological position may prove to be, they have so many characters in common with one another as to leave little doubt that they belong to the same class of animals.

Most authors, whether they regard *Turrilepas* and *Plumulites* as composed of four, six, eight, or even ten vertical columns of plates; whether they consider that the plates combine to form a cone-shaped body with the opening at the top, or a laterally flattened shell with five columns of plates on each side; or whether these fossils are considered to constitute the peduncle or capitulum; all agree in comparing them with the Cretaceous Cirripede *Stramentum* [= *Loricula*]. In such circumstances this agreement is certainly very remarkable.

Even the real structure of *Stramentum* was unknown to them, for it was not till recently (Withers, 1920) that it was shown that that Cirripede differed from all others, both recent and fossil, in that the rostral and carinal series of plates of the peduncle meet in free apposition, and that the carina is split lengthwise. In consequence of this modification of structure, one side of the shell could be parted from the other without injuring a single plate. In fact, *Stramentum* is one of the most aberrant types among the Cirripedia, and evidently represents a highly specialised side-line of development from the Scalpelliform barnacles, and did not persist beyond the close of the Cretaceous. It could not, therefore, have given rise to later Scalpellids, and it very probably arose from some such form as the Jurassic *Archaeolepas*.

It may be that the various authors ignore the Jurassic Cirripedes and institute a comparison with the Cretaceous *Stramentum* [= *Loricula*] merely because of the superficial resemblance of the multi-plated shell of the Palaeozoic *Turrilepas* to the loricated structure of the peduncle of *Stramentum*.

Prof. Gruvel (1905, p. 4) has gone further than most authors in the attempt to evolve *Stramentum* from *Turrilepas*, for he has illustrated his point by figures, and these have been reproduced in Lankester's Zoology. He considers that *Turrilepas* represents the complete imbricating covering of a primitive Cirripede, and has apparently based his conclusion on the figure of the specimen (H. Woodward, 1865, pl. xiv, fig. 1 h), which we

have seen constitutes only about the basal half of a shell. As I have shown already (1920, p. 81) Gruvel's figure exhibits five vertical columns of plates, and there were supposed to be five columns on the opposing side. While this figure certainly enables one readily to compare and to homologise the plates of *Turrilepas* with the five columns of the peduncle plates in *Stramentum*, the evidence for such a figure is quite imaginary. Had Gruvel known the precise structure of *Turrilepas*, in which the columns of plates number four only and combine to form an elongate blade-shaped shell, triangular in transverse section and opening along the narrow free margin, he would have realised the great difficulty in comparing *Turrilepas* with *Stramentum* [= *Loricula*], or indeed with any known Cirripede. In fact the real structure of the two forms is so fundamentally different that it is difficult to imagine any relationship between them.

Gruvel was justified, however, in considering the shell of *Turrilepas* to be the complete imbricating covering of the animal, for we now know that the soft parts must have been attached to the plates along the whole extent of the shell. It is, therefore, idle to talk of capitulum and peduncle, especially in connection with forms of which the zoological affinities are so uncertain.

At this point it is convenient to consider the evidence on which *Turrilepas* has been referred to the Cirripedia. H. Woodward (1865) adduced the following characters :—

(1) Ornament of plates.

(2) Overlapping points of plates directed upwards, or towards probable aperture of shell.

(3) Rows of imbricated plates with their intersecting edges, which cannot be compared with the plates of any other order except Cirripedia, unless it be the Echinoderma, from which they differ in the absence of any trace of crystalline structure, and in the sculpturing of the plates.

So far as the ornament of the plates is concerned, Woodward himself often stated that a similar ornament was seen in the Cystid *Ateleocystites* [i.e. *Placocystites*]. The upward direction of the overlapping points of the plates is a structure seen in other groups and is therefore not peculiar to the Cirripedia. Further, the plates were certainly not directed towards the aperture of the shell in the sense meant by Dr. Woodward, for he considered that the opercular plates were situated towards the upper extremity, or in the direction of the apices of the plates. Actually the shell opened along the whole extent of the sharp edge, or free margin. In Dr. Woodward's third point he admits a comparison with the Echinoderma, but a distinction from that group in the absence of any trace of crystalline structure. Even this last point is not wholly true, as we shall see later, and the sculpturing of the plates has already been dealt with.

It must be admitted from this that the evidence for the reference of *Turrilepas* to the Cirripedia is decidedly weak. So much did this seem to be the case that in my preliminary paper (1915) it was stated that it still remained to be proved that *Turrilepas*, *Plumulites*, and *Lepidocoleus* were Cirripedes at all.

Notwithstanding this, Dr. J. M. Clarke (1918) considered these forms to be the ancestors of the recent groups of stalked barnacles. Accepting Dr. Ruedemann's theory (1918) as to the origin of the sessile barnacles from the Phyllocarida, through the problematic Palaeozoic fossil *Eobalanus*, he attempted to show that the stalked Cirripedes were independently developed from the Phyllocarida through *Turrilepas*, etc. As a result of my criticism (1924) of the views held by Clarke and Ruedemann on the phylogeny of the Cirripedia, Ruedemann (1924) maintains the Cirripede nature of *Turrilepas* and its allies. In support of this he states that such a serious student of the Cirripedia as A. Joleaud (1916) has accepted them as Cirripedes even after my critical paper of 1915, and has included them in a new sub-order, the Protocirripedia, as also did Pilsbry (1916), who placed them in a new sub-order Turrilepadomorpha. Joleaud's support is not so strong as it appears, for he evidently did not understand the structure of these fossils. He followed Gruvel in erroneously considering *Turrilepas* to have a laterally flattened shell with five rows of plates on each side, an imaginary form which could the more easily be compared with *Loricula*. Moreover, he even accepted as Cirripedes the fossils described by Aurivillius (1892) as peduncles of *Scalpellum*. These fossils, solely through my drawing the attention of Dr. Bather to them (Bather, 1915, p. 49; Withers, 1915, p. 119), and not through some lucky find as Dr. Ruedemann states, were later shown by Dr. Bather to be the turret-like bases of the Edrioasteroid *Pyrgocystis*. So far as Dr. Pilsbry's action is concerned, it is more than probable that he included them in the new sub-order Turrilepadomorpha, not so much as signifying his belief in their Cirripede nature, but because he wished to separate them off from the Cirripedes included in the sub-order Lepadomorpha.

Dr. Ruedemann does not give any facts in support of his contention that *Turrilepas* and its allies are Cirripedes, and he even refrains from stating what he considers their precise structure to be. However, in view of my objections to the comparison of these fossils with the Cretaceous Cirripede *Loricula* by many authors, it is important that Dr. Ruedemann agrees with me that they cannot be directly connected with Mesozoic Cirripedes.

He states that *Turrilepas*, etc., look so strangely suggestive of primitive Cirripedes, and they concededly cannot be placed anywhere else. Moreover, on the basis of their structure it is wholly within the range of possibility that they—at least *Turrilepas*, *Plumulites*, and *Eopollicipes*—could have led to later barnacles. Further, he would consider the fact that they do

not fit into any other class as fair evidence, by exclusion, of their proper reference to the Cirripedia so long as they present even the remote resemblance they do to the latter in general structure and in the shape and sculpture of the plates, although he thinks this resemblance is not so remote in the case of *Eopollicipes*. Dr. Ruedemann lays stress on, and has drawn certain deductions from, the individual scarcity and minute size of these Palaeozoic forms. In the case of *Turrilepas* and *Plumulites* he states that the separate plates are never common and are mostly barely visible with the naked eye.

The fact that they do not fit into any other class could equally be advanced in support of *Turrilepas*, etc., being representatives of some new group. While some of the forms are rare, this is not the case with all of them, and out of some 322 specimens dealt with in this paper, 236 belong to five species, distributed as follows :—*Lepidocoleus ketleyanus* (33), *L. suecicus* (41), *Turrilepas wrightiana* (50), *Plumulites peachi* (55), and *P. scoticus* (57). As to their minute size, the species of *Lepidocoleus* admittedly have small plates (between 3 and 5 mm.), but these are readily seen, and the entire shell is far from small. It is clearly incorrect to describe the separate plates of *Turrilepas* and *Plumulites* as minute. The shell in *Lepidocoleus sigmoideus* has a length of more than 64 mm., in *Turrilepas wrightiana* about 60 mm., in *Plumulites bohemicus* more than 80 mm., and this is not unduly disproportionate to the length of any of the recent stalked barnacles.

Practically all that remains is the general resemblance in shape and sculpture of the plates, and how often has this not proved illusory! Even Darwin, among several authors, was misled by the general shape and ornament of the anterior ears of *Pecten*-like Molluscan shells into describing them as Cirripede plates (Withers, 1918, *Geol. Mag.*, p. 172). The similarity in ornament to Cirripedes and Cystids of the plates of these Palaeozoic fossils led Dr. H. Woodward to include *Turrilepas wrightiana* in the Cirripedia, and to regard a shell of *Lepidocoleus ketleyanus* as the stem of a Cystid.

If there is anything in this resemblance, then a median plate of *Turrilepas* or *Plumulites*, in shape and with a muscle-scar on its inner surface, should represent a scutum. In Cirripedes there is but a single pair of these plates, but in *Turrilepas* and *Plumulites* there are as many as two columns, each of thirty plates, precisely similar in shape, and in *Lepidocoleus* as many as sixty. Moreover, the inner surface of the plates shows not the slightest trace of ridges or lines of growth along their ad-apical margins; these lines of growth are characteristic of Cirripede plates, and are caused by the recession of the underlying membrane (corium) during the periodic growth of the valves. Sections of the plates do not give any suggestion that the plates are composed of successive laminae as they should do if they were Cirripedes.

Although perhaps the evidence is of no very great value, still it is a fact that no trace of chitin has been found in a chemical examination made by Mr. E. D. Mountain of plates of the forms from the Wenlock limestone of Dudley—*Turrilepas wrightiana* and *Lepidocoleus ketleyanus*.

The earliest known fossil that can be referred without any shadow of doubt to the Cirripedia is the Rhaetic form which C. Moore (1861) named *Pollicipes rhaeticus*; and the capitular valves of that form differ in no way from those of any ordinary recent stalked Cirripede. It agrees with every other stalked Cirripede, both recent and fossil, in that the paired scuta are the only valves of the capitulum that are adapted for the muscular attachment of the animal. The animal must have rested freely in the sack, and undoubtedly occupied the peculiarly curved position so characteristic of the recent Cirripedia.

How different is the structure of these Palaeozoic fossils! The soft parts must have been attached in *Lepidocoleus* to each of fifty-five plates, and probably more than sixty, on both sides of the shell in one of the earliest Ordovician species (*L. sigmoideus*), and to at least thirty plates on each side in the latest Devonian species (*L. latus*). In the Middle Silurian *Turrilepas* (*T. wrightiana*) the soft parts were attached to the plates of the keeled series, which in each of the two columns number at least thirty. In closely armoured Cirripedes the plates so fit and overlap each other that they form practically a rigid box, whereas in these Palaeozoic fossils the plates were apparently not only capable of movement one upon the other, but the animal was capable of bending the shell in certain directions. Moreover, if we orient these fossils with the apices of the plates in the same direction as in the more primitive types of stalked Cirripedes, then we see that in these fossils such modification as is shown in the plates would be not at the capitular end, but at the distal end, or where the stalk (or head) would be. Whichever way we look at these Palaeozoic fossils, they are not only inconsistent with the structure of Cirripedes, but with our knowledge of the phylogeny of the group.

If they be Cirripedes, then vast structural changes must have taken place between the close of the Devonian and the dawn of the Rhaetic, changes so great that it is difficult to see any connection between them and Mesozoic Cirripedes. This is precisely Dr. Ruedemann's view, for he says that the earlier ancestors of the Cirripedes must have been widely different from the fossils we meet first in the Mesozoic rocks; in fact so widely different that we could hardly expect to recognise them readily as Cirripedes without knowing the intervening stages. But surely we can recognise the Palaeozoic representatives of all other groups, and if these fossils were Cirripedes there seems to be no valid reason why we should not be able to recognise them as such.

The fact that the animals possessed a large number (up to sixty or more) of segmentally arranged adductor muscles indicates that, if they were Arthropods, the general plan of their structure must have been widely different from that of Cirripedes, and, indeed, from that of any Arthropods known to us. In view of this fundamental difference it is clearly impossible to attach much importance to the supposed agreement with Cirripedes in the superficial characters of the plates; and apart from this agreement there is nothing to suggest that they are Arthropods at all.

To what group then do they belong? As for *Turrilepas* being a *Chiton*, it may be seen that quite apart from the asymmetrical form of the plates, the two plates first described (Pl. VI, fig. 4) represent a right and a left keeled plate. They consequently could not have formed a unilinear series of plates as in the genus *Chiton*. Several hundred species of *Chiton* have so far been described, and all have in the adult shell a single row of eight plates, surrounded by a flexible girdle formed of the mantle edge, in which are minute plates or spicules. The separate plates of the fossil forms, especially those from the Carboniferous, do not differ widely in structure from the recent forms. In the Silurian *Turrilepas* there are not only four columns of plates, but they form a transversely triangular shell, opening along the whole extent of the narrow edge. The plates, therefore, could not have formed a flattened shell capable of attachment to rocks and stones, as is the case in *Chiton*. Moreover, the number of plates in a column is as many as thirty, and the whole shell is as unlike a *Chiton* as it is possible to be. The structure of the plates of *Turrilepas* does not commend their reference to any of the forms included in the Polyplacophora, and it seems impossible to uphold the view that *Turrilepas* is a Mollusc.

As for the Annelida, no reasons were given by Salter for his reference of *Turrilepas* (including *Turrilepas* and *Lepidocoleus*) to that group. It is certainly difficult to imagine these forms to be the shells of Annelids, presumably of the Polychaeta Tubicola, for we know that in both *Turrilepas* and *Lepidocoleus* the plates do not form a tube opening at one end as is the case in an Annelid tube. The shell must have opened in both forms along the whole extent of the sharp edge, for the scar in the two opposing series of keeled plates in *Turrilepas*, and of the two rows in *Lepidocoleus*, show that the soft parts must have been attached to those plates for the whole length of the shell. Nothing like this structure is known in the Annelida, for in that group the animal is able to move about freely in its tube. Moreover, no Annelid is known in which the shell is composed of such definite plates. In view of these facts, and of the structure of the individual plates, *Turrilepas* and *Lepidocoleus* can hardly be referred to the Annelida; although the shell, especially in *Lepidocoleus*, suggests some armoured Annelid.

We have now to consider whether *Lepidocoleus*, *Plumulites*, *Turrilepas*, and *Deltacoleus* can possibly be Echinoderms.

They have a geological range from the Lower Ordovician to the Middle Devonian, and this is similar to that of the Cystidea, which did not persist beyond the Carboniferous. It is also curious that almost always these fossils are found closely associated in the same beds with Cystids. They are obviously not the stems of Cystids as has been supposed, nor indeed part of any other organism, for they appear to be complete in themselves. Except that they have a similar ornament to that seen in the Anomalocystidae, there does not seem to be any other character suggestive of their reference to that group. Among the Edrioasteroidea there is a slight resemblance to the turrets of *Pyrgocystis*, for these are composed of columns of strongly imbricating and alternating plates combined to form a cylindrical stem, which does not, however, open along one edge as does the shell of *Turrilepas* and its allies. It has been suggested to me that these fossils might represent primitive armoured Holothurians, but this does not seem probable, especially since in those Holothurians which have plates, the plates are minute and scattered through the integument.

It is difficult, therefore, to make any close comparison with the total structure of the external form of any known Echinoderm, although there is always the possibility, having in mind the widely divergent forms included in the Cystidea, that these fossils might be shown to belong to that group or even some new group of Echinoderms just as anomalous as are the Cystids.

A recent Echinoderm has plates each composed of a meshwork of carbonate of lime which extinguishes uniformly between crossed nicols, and during fossilisation the interstices may become filled with crystalline carbonate of lime in optical continuity. In this way every plate and every spine will represent a single crystal of calcite. The original meshwork is often destroyed, but on the inner surface of the plates there usually remains a fine irregular reticular ornament. When broken across an Echinoderm plate shows cleavage characteristic of calcite, and this feature has been accepted by all authorities as conclusive evidence of Echinoderm stereom.

An examination of plates of *Lepidocoleus*, *Plumulites*, and *Turrilepas* shows that they all agree in having on their inner surface a similar reticular ornament to that seen on the inner surface of Echinoderm plates. In plates of *Lepidocoleus suecicus* from Sweden and England (Lake District), and *L. squamatula* from Bohemia, the plates when broken across show distinct crystalline cleavage. This feature is less distinctly seen in the specimens of *L. ulrichi* and *L. strictus* from the Ordovician and Silurian respectively of N. America, and in *L. latus* from the Middle Devonian of Moravia, but it is obviously not judicious to break these specimens to see if the cleavage is so definite

as it seems. A section of a plate of *L. squamatula* shows that the calcite completely extinguishes under crossed nicols, and it therefore acts as if it was a single crystal. Broken pieces of the shell of this species and that of *L. suecicus* from Sweden and England (Lake District) act in the same way.

Plates of *Lepidocoleus ketleyanus* and *Turrilepas wrightiana* from the Wenlock beds of Dudley do not show crystalline cleavage when broken across. The reticular ornament, however, is seen most clearly in the sections when cut near to the inner surface, but the texture of the whole plate is seen to be very finely granular and composed of minute grains. Under crossed nicols patches of the section extinguish simultaneously, showing that the grains in these areas have the same optical orientation. Small fragments of the crushed shell may extinguish simultaneously although showing the very fine granular texture, and appear to act as if they formed part of a single crystal.

Sections across the shell of *Plumulites peachi* from the Whitehouse group of Girvan, on the contrary, show that its texture is very coarsely granular, the grains being so large that the crushed shell examined between crossed nicols shows many fragments which are cleavage rhombs of single calcite crystals, and these appear to extinguish in patches under crossed nicols.

Of these three genera, which obviously belong to the same group, the fossilisation of the plate as a single crystal of calcite is seen only in certain species of *Lepidocoleus*. This condition is not reached in *Lepidocoleus ketleyanus*, *Plumulites*, or *Turrilepas*, and is therefore not characteristic of the whole group. The clear existence of the cleavage plates in *Lepidocoleus* shows that if they are not Echinoderms, then this condition of fossilisation is not restricted to Echinoderm stereom.

Whether they be accepted as Echinoderms or not, it seems difficult to refer them to any single group of that or of any other class, and for that reason they are here included in the new group Machaeridia. In any case it is hoped that our knowledge of these forms has been sufficiently advanced to serve as a more accurate basis for a discussion as to their systematic position. It must be admitted, however, that a discussion on this point with many authorities on other groups has only resulted in making it all the more probable that we have here representatives of a new group.

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Names of species are indexed under the trivial name (in *italics* and never with an initial capital) followed by the generic name.
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## PLATE I.

*Lepidocoleus sigmoideus* sp. nov. *Page* 10.

Middle Ordovician (Trenton group) : Belleville, Ontario, Canada.

Fig. 1. Shell showing right side. Holotype. × 1·5 diam. Brit. Mus., I.14841.

*Lepidocoleus ulrichi* sp. nov. *Page* 11.

Middle Ordovician (Trenton group) *Clitambonites* bed : Cannon Falls, Minnesota, U.S.A.

Fig. 2. Shell showing right side. Holotype. × 4 diam. Brit. Mus., I.7245.

Fig. 3. Fixed margin of same. × 4 diam.

*Lepidocoleus jamesi* (Hall & Whitfield). *Page* 12.

Upper Ordovician (" Hudson River " group) : Cincinnati, Ohio.

Fig. 4. Complete shell showing left side. × 2·3 diam. After J. M. Clarke, 1896, pl. vii, fig. 9.

Fig. 5. Single plate (right). Outer view. × 3 diam. Brit. Mus., In.17510.

Fig. 6. Inner view of same showing muscle pit. × 3 diam.

*Lepidocoleus grayae* Withers. *Page* 15.

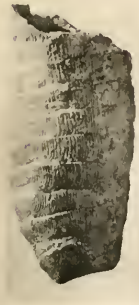
Upper Ordovician, Ashgillian (Drummuck group), Mudstones : Thraive Glen, Girvan, Ayrshire.

Fig. 7. Shell showing left side. Holotype. × 3 diam. Brit. Mus., In.21648.

Fig. 8. Fixed margin of same. × 3 diam.

Fig. 9. Enlarged view of the two lowermost plates of same from right side showing ornament. × 10 diam.

Fig. 10. Another shell showing left side. × 3 diam. Brit. Mus., In.21649.



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LEPIDOCOLEUS

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## PLATE II.

*Lepidocoleus suecicus* Moberg. *Page* 27.

Upper Ordovician, Black Trinucleus Shales : Svälasgård, near Skattungbyn, Dalecarlia.

Fig. 1. Part of a shell with the plates displaced, some showing the inner surface with muscle-scar. × 3 diam. Squeeze from natural mould of Lectoholotype. Brit. Mus., I.14425.

Upper Ordovician, Ashgillian : Windermere, Lake District.

Fig. 2. Single plate (right). × 3 diam. Troutbeck. Brit. Mus., In.23973.

Fig. 3. Single plate (right). × 3 diam. Pull Beck. Sedgwick Museum, Cambridge (Turnbull Coll., No. 46).

Upper Ordovician, Caradocian, *Dicranograptus* Shales, *Orthis argentea* beds : Spittal Road Cutting ?, Treffgarne, Haverfordwest.

Fig. 4. Single plate (right). Squeeze from natural mould. × 3 diam. Sedgwick Museum, Cambridge (Turnbull Coll., No. 4071).

Upper Ordovician, Ashgillian, Shoalshook Limestone : Shoalshook Railway Cutting, Shoalshook, Haverfordwest.

Fig. 5. Single plate (left). Squeeze from natural mould. × 3 diam. Sedgwick Museum, Cambridge (Turnbull Coll., No. 3778).

*Lepidocoleus turnbulli* sp. nov. *Page* 31.

Lower Silurian, Lower Valentian, Haverford Stage, Cartlett Beds : St. Martin's Cemetery, Haverfordwest.

Fig. 6. Single plate (right). Squeeze from natural mould. Holotype. × 3 diam. Sedgwick Museum, Cambridge (Turnbull Coll., No. 1839).

*Lepidocoleus birmanicus* sp. nov. *Page* 32.

Lower Silurian, Panghsa-pye beds (= Llandovery) : Panghsa-pye, Northern Shan States, Burma.

Fig. 7. Single plate (left). Squeeze from natural mould. × 3 diam. Brit. Mus., In.18383.

Fig. 8. Single plate (right). Squeeze from natural mould. Holotype. × 3 diam. Sedgwick Museum, Cambridge.

*Lepidocoleus squamatula* (Barrande). *Page* 29.

Upper Ordovician ($d^3$) : Mt. Kosow, Bohemia.

Fig. 9. Single plate (left). × 3 diam. Brit. Mus., In.17504.

*Lepidocoleus britannicus* sp. nov. *Page* 23.

Middle Silurian, Lower Salopian, Wenlock Beds : Malvern, Worcestershire.

Fig. 10. Shell showing left side. × 3 diam. Holotype. Brit. Mus., I.5032.

Fig. 11. Same viewed from fixed margin. × 3 diam.

Fig. 12. Enlarged view of plates to show ornament. × 10 diam.

*Lepidocoleus strictus* sp. nov. *Page* 17.

Lowest Silurian (Richmond group) : Versailles, Indiana, U.S.A.

Fig. 13. Shell showing right side. × 4 diam. Holotype. Brit. Mus., I.7244.

Fig. 14. Same viewed from the fixed margin.

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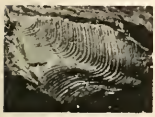

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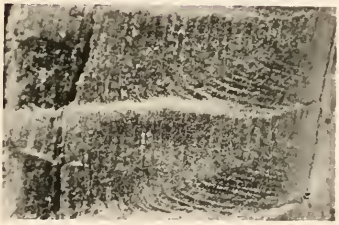

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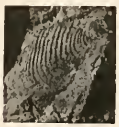

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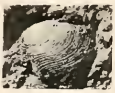

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## PLATE III.

*Lepidocoleus ketleyanus* (Reed ex Salter MS.). *Page* 20.

Middle Silurian, Lower Salopian, Wenlock Beds : Dudley, Worcestershire.

Fig. 1. Remains of a shell with the plates much displaced. One of the two syntypes (lectoholotype). × 3 diam. Sedgwick Mus., Cambridge, No. 220.

Fig. 2. Shell with the distal plates telescoped, the proximal part upturned and laid at the side of the displaced plates of the middle of the shell. × 3 diam. I.16264.

Fig. 3. Nearly complete shell showing left side, and a few displaced plates near proximal end. × 1·5 diam. 59058.

Fig. 4. Shell showing left side with both extremities curled towards the free margin. × 3 diam. I.16307.

Fig. 5. Shell (middle part viewed from the right side). × 3 diam. (Origl. figd. H. Woodward, 1880, as stem of *Placocystites forbesianus*.) In.17508.

Fig. 6. Same viewed from fixed margin.

Fig. 7. Same viewed from free margin.

Fig. 8. Shell with the plates more or less displaced. × 1·5 diam. I.540.

Fig. 9. Plates enlarged to show ornament. × 10 diam. I.16260.

Fig. 10. Inner view of plate (right) showing muscle-scar. × 10 diam. I.16260.

(Except Fig. 1, all the specimens are in the Geological Department of the British Museum.)

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## PLATE IV.

*Lepidocoleus sarlei* J. M. Clarke. *Page* 17.

Middle Silurian, Clinton group : Rochester, New York.

Fig. 1. Almost complete shell from the right side. × 2·3 diam.
Fig. 2. Same from left side.
Fig. 3. Same from fixed margin.
Fig. 4. Same from free margin.

(Figures of holotype, after Clarke, 1896, figs. 1–4.)

*Lepidocoleus polypetalus* J. M. Clarke. *Page* 25.

Lower Devonian, Lower Helderberg group : Albany Co., New York.

Fig. 5. Incomplete shell showing left side. × 2·3 diam.
Fig. 6. Part of other side of specimen showing fixed margin and alternation of plates. × 2·3 diam.

(Figures of holotype after Clarke, 1896, figs. 7, 8.)

*Lepidocoleus illinoicnsis* Savage. *Page* 25.

Lower Devonian, Upper Oriskany group (Clear Creek Chert) : Union Co., Illinois.

Fig. 7. Incomplete shell showing left side, with the plates of the right side projecting slightly. × 2¼ diam.
Fig. 8. Same viewed from fixed margin showing alternation of plates.
Fig. 9. Separate plate (right) to show ornament. × 1·5 diam.

(Figures after Savage, 1913, figs. 1–3.)

*Lepidocoleus latus* sp. nov. *Page* 26.

Middle Devonian : near Olomouc, Moravia, Čecho-slovakia.

Fig. 10. Incomplete shell showing left side. × 3 diam. Remeš Coll.
Fig. 11. Same viewed from fixed margin.

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## PLATE V.

*Turrilepas wrightiana* (de Koninck). *Page* 37.

Middle Silurian, Lower Salopian, Wenlock Beds : Dudley, Worcestershire.

Fig. 1. Complete shell with the left side and back exposed, and a portion of the proximal plate preserved. × 1·5 diam. 59164.

Fig. 2. Enlarged view of proximal portion of same, to show relation of plates. × 5 diam.

Fig. 3. Proximal half of shell with left side and back exposed, and the proximal plate missing. This is the original of Dr. H. Woodward's fig. 1 h. × 1·5 diam. I.16272.

Fig. 4. Right side of same showing part of inner surface of the left series of plates.

Fig. 5. Nearly complete shell with the left side exposed and three plates of the right side curving beneath the proximal end. × 1·5 diam. 59406.

Fig. 6. Proximal portion of a shell with the plates of the four columns spread out, and the proximal plate preserved. × 3 diam. 47871.

(All the specimens are in the Geological Department of the British Museum.)

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## PLATE VI.

*Turrilepas wrightiana* (de Koninck). *Page* 37.

Middle Silurian, Lower Salopian, Wenlock Beds: Dudley, Worcestershire (except fig. 8, which is from Malvern).

Fig. 1. Proximal end of specimen 47871 (Pl. V, fig. 6) from the left side, enlarged to show proximal plate and its relation to the adjacent plates. × 9 diam.

Fig. 2. Incomplete shell showing the right side, with several of the plates displaced near the middle. Original of Dr. H. Woodward's fig. 1 g, but, unlike that figure, it shows the kite-shaped plates. × 1·5 diam. 59057.

Fig. 3. Incomplete shell showing the keeled and kite-shaped plates of the left side. × 1·5 diam. 59056.

Fig. 4. Keeled plates (right and left). Outer view. Holotype. × 3 diam. I.16283.

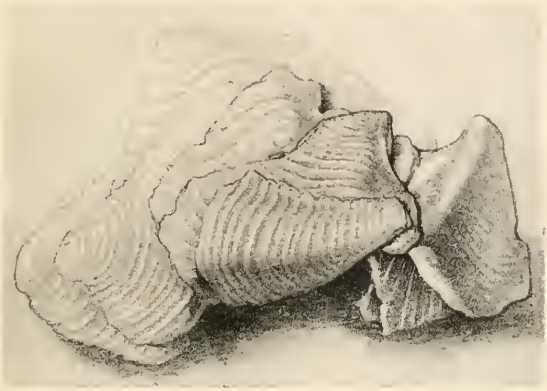
Fig. 5. Keeled plate (right). Inner view showing muscle-scar. × 2·5 diam. In.25812.

Fig. 6. Keeled plate (left). Inner view showing muscle-scar. × 2·5 diam. In.25813.

Fig. 7. Keeled plate (right). Inner view showing muscle-scar. × 2·5 diam. In.25814.

Fig. 8. Kite-shaped plate (right). × 3 diam. I.16308.

(All the above specimens are in the Geological Department of the British Museum.)



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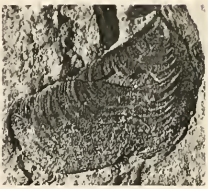

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## PLATE VII.

*Plumulites peachi* (Nicholson & Etheridge, jun.). *Page* 51.

Upper Ordovician, Caradocian, Whitehouse group: Whitehouse Bay, Girvan, Ayrshire.

Fig. 1. Shell (middle portion) showing relation of keeled plates to the kite-shaped plates. Lectoholotype. Inner view. × 3 diam. In.23650. (Origl. figd. Nich. & Ether., 1880, pl. xx, fig. 8; Reed, 1908, fig. 4.)

Fig. 2. Nearly complete shell, lacking only the proximal end, the keeled plates crushed together. Inner view. × 1·5 diam. In.23672.

Upper Ordovician, Ashgillian, Drummuck group (Mudstones & Starfish Bed): Thraive Glen, Girvan, Ayrshire.

Fig. 3. Nearly complete, although badly preserved, shell, lacking proximal end. Outer view. × 2 diam. Starfish Bed. (Origl. figd. Reed, 1908, fig. 1.) In.23640.

Fig. 4. Keeled plate (right). Inner view, showing what is probably a muscle-scar. × 4 diam. Mudstones. (Counterpart figd. Reed, 1908, fig. 2.) In.23648.

*Plumulites scoticus* (R. Etheridge, jun.). *Page* 64.

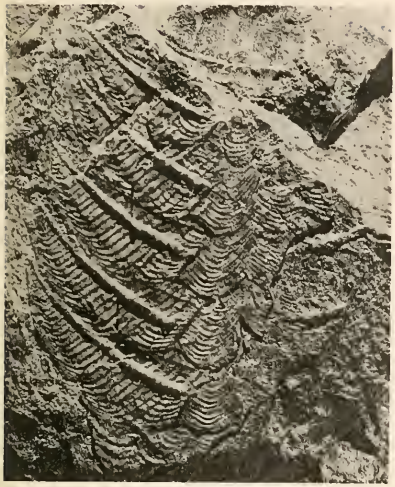
Upper Ordovician, Caradocian, Balclatchie group: Girvan, Ayrshire.

Fig. 5. Keeled plate (right). Outer view. × 4 diam. Balclatchie. In.23707.

Fig. 6. Kite-shaped plate. × 4 diam. Balclatchie. In.23681.

Fig. 7. Cancellated plate. × 4 diam. Dow Hill. (Origl. figd. Reed, 1908, fig. 10.) In.23712.

(All the specimens are in the Geological Department of the British Museum.)



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## PLATE VIII.

*Plumulites bohemicus* Barrande. *Page* 49.

Lower Ordovician ($d^1$) : Wosek, Bohemia.

Fig. 1. Shell (middle part). Squeeze (In.24170) taken from counterpart of lectoholotype (Barrande, 1872, pl. xx, fig. 1). Nat. size. (Original in Roy. Bohemian Mus.)

*Plumulites folliculum* Barrande. *Page* 50.

Lower Ordovician ($d^2$) : Trubsko, Bohemia.

Fig. 2. Nearly complete shell. Squeeze (In.24172) taken from counterpart of syntype (Barrande, 1872, pl. xx, figs. 15–16). × 1·5 diam. (Original in Roy. Bohemian Mus.)

*Plumulites llanvirnensis* sp. nov. *Page* 57.

Lower Ordovician, Skiddavian, Lower Llanvirn series, *Didymograptus bifidus* zone : Long Plantation Cutting, near Scolton, Pembrokeshire.

Fig. 3. Keeled plate. × 1·5 diam. Sedgwick Mus., Cambridge (Turnbull Coll., No. 3847).

Fig. 4. Kite-shaped plate. Holotype. × 3 diam. Sedgwick Mus., Cambridge (Turnbull Coll., No. 3608).

*Plumulites trentonensis* sp. nov. *Page* 60.

Middle Ordovician, Middle Trenton Beds : Port Schuyler, Albany Co., New York.

Fig. 5. Kite-shaped plate (left). Holotype. × 10. After Ruedemann, 1901, pl. ii, fig. 11.

*Deltacoleus crassus* gen. et sp. nov. *Page* 43.

Upper Ordovician, Caradocian, Balclatchie group : Girvan, Ayrshire.

Fig. 6. Keeled plate. × 2 diam. Dow Hill. Brit. Mus., In.23673. (Origl. figd. Reed, 1908, fig. 6.)

Fig. 7. Keeled plate. Holotype. × 4 diam. Balclatchie. Brit. Mus., In.23708. (Origl. figd. Nich. & Ether., 1880, pl. xiv, fig. 25; Reed, 1908, fig. 13.)

Middle Ordovician, Llandeilian, Barr Series, Stinchar Limestone : Aldons, Girvan, Ayrshire.

Fig. 8. Kite-shaped plate. × 3 diam. Brit. Mus., In.23737.

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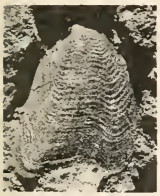

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